CAN YARDSTICK COMPETITION WORK ? A STUDY OF THE WATER AND SEWERAGE INDUSTRY IN ENGLAND AND WALES.

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Declaration.

This thesis consists entirely of my own original work and has been composed by myself.

Signed: J. W. Saunders

To my father and in memory of my mother.

(John ch 4 vv 13-14)

Contents.

Abstract.

Under the terms of the Water Act 1989, the Office of Water Services (Ofwat) was established and given responsibility for the economic regulation of the English and Welsh water industry. One of the concepts underpinning the new regulatory regime was comparative or 'yardstick' competition. Implementation of the regime required the establishment of a methodology for comparative efficiency measurement.

The thesis presents econometric results from estimates of a series of ordinary and stochastic frontier cost functions. These are used to compare the efficiency of operators in both the water supply and sewage treatment branches of the industry. A new water supply database covering the period 1977/86 is constructed for the purpose, and the comparative efficiency rankings for both branches of the industry are shown to be robust.

Fieldwork methods are used to analyse the role of yardstick competition in the regulatory regime and the way in which the comparative efficiency results could be applied. The fieldwork covers twelve interviews with officials of water companies, and one with the Director General of Water Services. Based on results of both quantitative and qualitative work, conclusions are drawn as to whether yardstick competition is a more widely applicable regulatory device.

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My greatest debt is to my family, for their unfailing encouragement and support.

A Note on Company Identification.

To preserve the anonymity of water industry interviewees their personal and company names have been withheld from the text. A confidential appendix setting out the schedule of interviews is available to the examiners.

Chapter 1.

Introduction.

In UK economic policy terms, privatisation was one of the dominant themes of the last decade. Domestically it quickly took root, flourishing in a favourable economic and political climate. Internationally, countries such as France, West Germany and the Netherlands followed the pioneering British example more hesitantly. Nevertheless, within a decade the face of British industry had been transformed; the movement had gathered momentum in Europe; whilst privatisation campaigns had begun to emerge in former communist states such as Russia and Poland.

In one sense the term 'privatisation' is a piece of shorthand. A generic word which, when used rather loosely, may refer to industrial policies ranging from the sale of public sector assets to the contracting out of refuse services. However in the economic literature it is generally used to describe the transfer of assets or service functions from public to private ownership and control[1]. In the British context, three elements of privatisation policy have become focal points for the economic debate, namely: ownership, competition and regulation[2]. Property rights theory has been employed in the analysis of the ownership question as shares in publicly owned companies have been offered for sale to private investors[3]. Contestability considerations have been

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[1] For example, see Kay and Thompson (1986).

[2] In their classic textbook treatment of the issue Vickers and Yarrow (1988) employ these three headings for the theoretical discussion of privatisation.

[3] Boardman and Vining (1989) take a property-rights approach in a recent paper examining ownership and performance in a competitive environment.

prominent in the discussion of competition policy and the liberalisation of trading conditions[4]. Principal-agent, game-theoretic results have been used in the analysis of new regulatory arrangements with the emergence of semi-autonomous government bodies such as Oftel, Ofgas, Offer and Ofwat[5]. Privatisation is today understood within a wide range of separately evolving areas of research.

However, these three facets of policy do not receive equal political and media attention at any one time. For example, in the UK, a government announcement of its intention to privatise an organisation or industry has invariably led to the question of ownership becoming the immediate focus of discussion. This was perhaps most marked at the time of the privatisation of utilities such as gas, water and electricity[6]. All these industries have some natural monopoly characteristics and long histories of public ownership. But in these and other instances, once the reallocation of property rights had been completed, the spotlight moved away from ownership and on to the questions of competition policy and regulation[7]. And whilst competition policy exercised the minds of politicians,

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[4] For example, Harrison and McKee (1985) present some experimental evidence in investigating a variety of methods of regulatory control as alternatives to increasing market contestability.

[5] Vickers and Yarrow (1988) employ the work of Baron and Myerson (1982) in this way; discussing a model of regulation under conditions of asymmetric information.

[6] For water the publication of Littlechild's report to the Department of the Environment (Littlechild 1986) was a catalyst for heightened media interest in the ownership issue. See for example Evans, R. 'Dangerous Currents in the Privatisation Pool' Financial Times 5/2/86.

[7] Thus a Financial Times survey of the water industry published two years after privatisation of the water authorities highlighted regulation and competition, rather than ownership, in its analysis. (Financial Times 22nd November 1991)

professional economists and high-ranking businessmen, it was regulation which, arguably, came closest to capturing the public imagination[8]. Consequently the issue moved up the political agenda where it has remained.

These policy reforms took place against a background of rising interest in the economic theory of regulation: one product of which was the development of a theory of 'yardstick competition' by Shleifer[9]. In a 1985 Rand Journal article, he proposed a system of regulation in which the price that a regulated monopolist would receive would depend on the costs of identical firms. By operating under this regime he argued that firms would choose socially efficient levels of cost reduction. The mechanism was shown to generalise to cover heterogeneous firms with observable differences. In the following year, Stephen Littlechild referred to the theory in his influential report to the Government on the privatisation of the ten English and Welsh Water Authorities[10]. It was argued to be an appropriate regulatory solution where companies exercised considerable local monopoly power, and was adopted, in modified form, in the final privatisation settlement.

Two factors then motivate the thesis. Firstly the continued debate and interest over the efficacy of UK utility regulation. Secondly the development of a new theory of regulation, yardstick competition. A theory which attracts by its simplicity and yet is powerful in its conclusions. This locates the research firmly within the wider

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[8] The phenomena is unsurprising given the highly technical nature of many proposals for the reform of competition policy.

[9] Shleifer, A. (1985) ' A theory of yardstick competition' Rand Journal of Economics, vol 16, pp319-27.

[10] Littlechild (1986).

privatisation debate under the sub-heading of regulation. We ask, 'Can Yardstick Competition work?' and in seeking an answer turn to the water and sewerage industry in England and Wales as an appropriate testbed.

The aims of the thesis may be stated as follows. The general aim is to analyse, and develop the understanding of yardstick competition as it operates in the English and Welsh water industry. The subsidiary aims are: to develop (and illustrate the workings of) a tractable means of comparative efficiency measurement for the industry, and to establish whether there are any general principles which would guide a policy maker towards or away from employing a similar regulatory solution in other industries. In other words, can regulation by yardstick competition work for water? Is it a more widely applicable regulatory device?

In addressing these questions the study has several distinctive features. First it examines a regulatory system still in its infancy, whose workings in the UK remain largely unexplored. Second it uses the English and Welsh water and sewerage industry as an empirical testbed. The choice of industry is entirely appropriate given the theoretical setting of the work. Yardstick competition was proposed by Shleifer as a device for the regulation of monopolists providing similar or identical services in different geographical locations. Therefore an industry, such as water, consisting of a series of local natural monopolies would supply the most appropriate empirical observations[11]. However, until fairly recently, the UK water industry has been neglected by econometricians. Papers by Ford and Warford (1969) and Knapp (1978) are now

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[11] Littlechild noted in his report to the Department of the Environment (1986) that "The UK water industry is thus the natural monopoly par excellence." (p5)

very dated, but remain the two most widely cited pieces of empirical work for the UK industry. The thesis presents updated econometric results based on an entirely new database constructed for the purpose. Technically, the estimation of a series of stochastic frontier cost functions for comparative efficiency measurement advances previously published work for the industry. This is also true of the fieldwork undertaken and presented as qualitative evidence on the operation of the new regulatory regime.

The study has four major results. First, that econometric methods may be employed in obtaining a robust set of comparative efficiency rankings for both water supply and sewage treatment functions. It is argued that these could be used by the Regulator of the industry to improve the regulatory outcome. Second, that the principle of yardstick competition had underpinned the 1989 regulatory settlement, and had continued to influence the direction of industrial policy. Third, that performance incentives for company management had been enhanced since the introduction of the new regulatory regime. And although the system suffered from severe imperfections at present the outlook was more positive given the ongoing improvements in the quality of data and sophistication of analytical techniques available. Finally, that general principles could be established in the light of the research, which would guide a policy maker towards or away from employing a similar regulatory solution in other industries.

The thesis is split into eight chapters. Following the introduction chapter two sets out the theory of yardstick competition; critically assessing its advantages and drawbacks. Chapter three presents methodology and a survey of recent econometric work relating to the modelling of producer behaviour. Chapters four and five present the results of econometric work in making comparative efficiency assessments. Chapter six outlines field research methodology used in the second half of the work, and chapter seven presents the results. Chapter eight concludes.

So if, as Vickers (1991) maintains,

> "Regulatory economics in Britain is only at the end of the beginning"[12]

this thesis may be seen as a relatively early contribution to a body of research only just emerging from its infancy.

[12] Vickers (1991), p29.

Chapter 2.

Yardstick Competition: The Development of a Theory of Regulation.

Introduction.

The theory of yardstick competition may be traced to the work of Shleifer (1985). In an influential Rand Journal article he presented a system of monopoly regulation which drew its inspiration from the comparison of firms. The system, it was argued, would serve a dual purpose. First, it would lead to the revelation of the cost minimising potential of every firm; second, it would establish an incentive structure appropriate to the achievement of that potential. By comparing the costs of similar firms the regulator would establish a set of 'benchmarks' of performance from which he could infer any one firm's attainable cost level. By establishing a pricing formula in which the price received by a monopolist depended on the financing requirements of firms, the regime would reward competitive behaviour. This system he labelled 'yardstick competition'.

The scheme neatly avoided some of the pitfalls inherent in other regulatory systems. For under rate of return or cost plus regimes, prices generally tracked costs, giving the monopoly supplier little incentive to cost minimise. In the absence of competitive pressure X-inefficiencies added to the welfare loss. The problem, which appeared insurmountable, was how to bring together firms separated in space to enable them to compete. Yardstick competition overcame the problem in the following way.

Shleifer considered a situation in which two firms, identical in every respect, served identical markets, distinguished only by their geographical location. The appointed regulator would obtain comparative cost information for both, adopting the lower figure as his benchmark, standard or yardstick. The low cost firm would be rewarded - for example, by a price increase - and the high cost firm penalised. The process would be repeated at a later date, meanwhile both firms would have an incentive to ensure their costs were minimised at the time of the next round. In this way, by making comparisons at discrete intervals, continuous competitive pressure would be applied to both firms.

The result requires that the strong assumptions of identical competitors and environment should hold. Any deviation from these conditions would allow yardstick competitors to contend that their inherent heterogeneity led to the observed cost differences. Shleifer went on to show that if this heterogeneity could be controlled for perfectly, the result would carry over. Continuous competitive pressure would be exerted and a socially efficient level of cost reduction employed by each firm.

The apparent simplicity of the scheme gives little clue to its theoretical pedigree. But its descent may be traced through several distinct ideas explored relatively recently in the economic literature. This chapter presents a critical examination of the theory itself, of the proposal that it be used as a regulatory device for the English and Welsh water industry and of its workings since privatisation.

Development of the Theory.

The theory of yardstick competition is first and foremost a theory of monopoly regulation of particular relevance to the regulation of natural monopolies. But within it are the problems of agency and asymmetric information which have attracted much attention in the economic literature in recent years. For the discussion of yardstick competition, one issue may be seen as being nested within another. Thus the central problem of asymmetric information may be regarded as being nested within the concerns of principal agent analysis which are in turn nested within the overall problem of monopoly regulation. In order to get to the heart of the problem it will be necessary to begin with the outer skin of the theoretical onion.

The problem of monopoly regulation in general, and natural monopoly regulation in particular has proved fertile ground for economic debate since well before the time of Adam Smith. For natural monopolies, theorists were apparently unwilling to deny a logic which carried any discussion of scale economies in production to monopoly prices in the market place. A large literature grew up around the various methods of utility regulation, which in time came to be balanced by an equally large literature criticising the suggested techniques. In a celebrated contribution to the debate Stigler and Friedland (1962) questioned whether there was any evidence at all to suggest that public regulation had a discernable effect. Public regulation looked in danger of taking on the appearance of an empty box making little or no difference to the activities of an industry.

In 1968 Demsetz challenged the received orthodoxy by arguing that the existence of a natural monopoly did not necessarily imply monopoly prices given an elastic supply of potential bidders for a monopoly contract (franchise) and prohibitive collusion costs by potential suppliers. Resurrecting Chadwick's (1859) distinction between competition for the field and competition within the field, Demsetz showed that competition at the franchise award stage would be sufficient to reduce the price of a service below the monopoly level even though increasing returns would imply that only one firm would supply. The argument was not that regulatory agencies were undesirable per se, rather,

> "It is my belief that the rivalry of the open market place disciplines more effectively than do the regulatory processes of the commission."[13]

The result was striking in its theoretical simplicity but difficult to implement given the rather strong assumptions underpinning it. Nevertheless one important theme of the theory of yardstick competition may be traced to this contribution. Namely the idea that competition in one form or another may be relied upon to promote the efficient allocation and use of resources even under apparently hostile conditions. For Demsetz, the auctioning of franchises was the institutional device to allow competitive pressures to curb the pricing excesses of monopolistic behaviour. As before, others were quick to point out the many practical difficulties which dogged the award and monitoring of contracts. Williamson (1976) concluded that in many cases the franchise solution may not be superior to conventional regulation and that consequently the regulator would not wither away. But the importance of Demsetz to the development of the theory of yardstick competition lay not in the insights it offered into the franchise auctioning process, but in the affirmation that competitive devices, of whatever sort, may be put to good use in the conduct of regulatory policy.

Over the last quarter century methodological advances in the economics of incentives and incomplete information have done much to influence the regulation literature.

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[13] Demsetz (1968) p65.

Traditionally, economic theory had little to offer by way of explanation as to how non-market organisations like firms worked. Consequently analysis of the regulatory process was restricted. More recent developments of the information literature have done much to lift some of these restrictions. The principal-agent literature is one such development which has contributed to the theory of yardstick competition.

Regulation itself may be regarded as a principal-agent problem in which the principal, or regulator, voluntarily attenuates his property rights to permit an agent, or regulatee, to act on his behalf. Models of this sort reveal quite clearly two basic features of the regulatory relationship: namely, incomplete information, and goal conflict. Levinthal (1988), in a survey of agency models argues that these agency models are a neoclassical response to questions regarding the behaviour of an organisation of self-interested agents with conflicting goals in a world of incomplete information. Typical of this sort of approach is the work of Baron and Myerson (1982)[14] who present a model of regulation where the firm but not the regulator has access to cost information. A feasible incentive-compatible regulatory policy is derived that maximises social welfare and ensures that the firm has no incentive to report its costs untruthfully. Laffont and Tirole (1986) extend the approach assuming that costs are influenced by the firm's cost reducing effort and that the regulator may observe costs but not effort or the state of nature. Again the optimal regulatory regime is outlined given the available information.

However these, although articulating the regulatory problem within a principal agent framework do not feed in to the

[14] See also Baron and Besanko (1984) where the regulator observes a firm's marginal cost ex post with observation error.

theory of yardstick competition as clearly as other strands of the literature. And it may be argued that this literature, was at least partially inspired by the early work done by regulatory commissions, particularly in the USA.

Although Shleifer formalised the approach to using cost comparisons at discrete time intervals for regulation, this 'yardstick' device had been employed in one form or another throughout the twentieth century in the USA. For example, Nash (1925) noted that by the 1920s the Wisconsin and Illinois Regulatory Commissions had developed quite elaborate schemes for grading, or ranking, the efficiency of utilities under their jurisdiction.

In the following decades the US electricity and defence contracting industries employed similar approaches to encourage effective regulation and low cost procurement[15]. However, it was Iulo (1961) who published work in which he used a formal statistical technique - regression analysis - in his attempt to identify efficient and inefficient firms in a cross section of US electric utilities.[16]

Following important papers discussing contractual incentives and incentive pricing within a regulatory context by Scherer (1964) and Cross (1970)[17], Sherman (1980) showed that the setting of prices or evaluation of performance by reference to other firms' contemporaneous costs, motivated socially efficient input choices. These input choices were held to be free of the bias that was

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[15] See, for example, Johnson (1985).

[16] Schmalensee (1979 p130) notes that the technical weaknesses of some of Iulo's procedures may have discouraged regulators from adopting this more sophisticated approach to comparative efficiency measurement.

[17] See also Holthausen (1979).

possible under rate of return regulation. Holmstrom (1982) and Mookherjee (1984) argued that in a principal agent setting, with multiple agents and asymmetric information, it was generally the case that improved incentive contracts for agents would be attained if the reward for each agent was to some extent contingent on the performance of all other agents, as well as his own. The result was strengthened to the extent that agents faced similar conditions. Holmstrom (1982) went on to demonstrate that this comparative competition among agents was useful first and foremost as a device for extracting information.

The tournament literature developing at this time took up the point. Green and Stokey (1983), for example, present an elegant analysis of a situation in which a risk neutral principal employs a group of identical risk-averse agents. Each agent's output is deemed to depend on his own effort and a common disturbance term. If the distribution of the common disturbance term is sufficiently diffuse then a tournament, in which agents are ranked and only the 'winner' receives the payoff, dominates the use of optimal independent contracts.[18] The tournament, in effect, eliminates the uncertainty associated with the common disturbance terms while adding only a minor element of uncertainty associated with the agent's private signal. Asymptotically, the result holds as the number of agents or the variance of the common disturbance term increase. Indeed, the effect is more pronounced the larger are the two variables.[19]

[18] Lazear and Rosen (1981) derive an analogous result in the context of labour markets finding the tournament solution dominates a linear piece rate.

[19] Empirically, the implication is that tournament contracts should be found in employment relations in which the shared element of uncertainty is relatively great.

In addition Nalebuff and Stiglitz (1983b) argue that tournament systems based on relative performance have an advantage over conventional systems that pay relative to outcome only. They are more flexible. For example, if a technological advance makes the performance targets easier to reach then a conventional system has to be rebased. But a system based on relative performance automatically adjusts as everyone does better.

From this it is a short step to Shleifer's yardstick competition in which, instead of agents being granted tournament contracts, they are evaluated relative to the performance of other agents. As the number of agents increases the comparison mitigates the effect of uncertainty associated with the common disturbance term, leaving only the uncertainty associated with the agent's idiosyncratic risks.

The key result, however, in terms of the tractability of yardstick competition as a regulatory device was presented independently by Holmstrom (1979) and Shavell (1979). These two authors both drew on earlier work by Harris and Raviv (1976, 1978) who posed the question concerning the value of information in a principal-agent setting. Given that asymmetry characterised the relationship the question was whether information (about the agent's effort) supplied to the principal was of value if that information happened to be imperfect. Where incentives diverged (ie goal conflict) and information was asymmetric would imperfect monitoring improve the outcome?

Holmstrom demonstrated that it did.

> "It is shown that any additional information about the agent's action, however imperfect, can be used to improve the welfare of both principal and the agent. This result, which formalizes earlier references to the value of monitoring in agency relationships (Stiglitz 1975,

Williamson 1975) serves to explain the extensive use of imperfect information in contracting."[20]

Both Holmstrom (1979) and Shavell (1979) proved that any informative signal, regardless of how noisy it was, would be of positive value if obtained costlessly. The result is perhaps counterintuitive, for it may be expected that a noisy signal would compound the uncertainty and so be of less value in establishing a contract. But the point is made quite clearly by Holmstrom,

> "We have studied efficient contractual agreements in a principal-agent relationship under various assumptions about what can be observed, and hence contracted upon by both parties. When the payoff is observable, optimal contracts will be second-best owing to a problem of moral hazard. By creating additional information systems (as in cost-accounting, for instance), or by using other available information about the agent's action or the state of nature, contracts can generally be improved."[21]

The improvement in contractual arrangements brought about by the use of imperfect information is the second foundation on which yardstick competition rests. Given that even noisy information has some value, by making imperfect cost comparisons between agents the regulator, or principal, is able to produce a superior outcome to that pertaining were the information not used.

In a more technical paper Shavell (1979) comes to the same conclusion by a different route. Given that the fee paid by the principal to a risk averse agent is a function of the outcome and the agent's effort, imperfect information is always of value. He continues,

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[20] Holmstrom (1979) p75.

[21] Holmstrom (1979) p 89.

"...we are not assuming that effort is necessarily observed with complete accuracy. Thus, the use of information about effort would introduce the new risk that the fee might reflect an inaccurate perception of the agent's true effort. Other things being equal the introduction of a new risk is, of course, undesirable for the agent; and, if the principal is risk averse, it is undesirable for him too. Consequently, there is a real question whether the information is useful...we prove that (v) if the agent is risk averse, his fee would always depend to some extent on the information which the principal has about his effort - the information is always of value; this result has been independently proved by Holmstrom (1979)."[22]

The result validates the use of imperfect information for the purposes of yardstick comparison. Without it, Shleifer's system of regulation is as practically unworkable as that of Loeb and Magat (1979). With it, the system is an important policy option for regulatory authorities. To highlight its tractability Shleifer's model will now be outlined in detail.

Yardstick Competition: The Theory.

Shleifer (1985) presents the basic theory of yardstick competition using a simple one-period model in which N identical, risk-neutral firms operate in a certain environment. Each firm serves a different market but faces an identical downward sloping demand curve, $q(p)$. c_o represents the initial marginal cost profile of each firm. By investing in cost reduction activity, $R(c)$, marginal costs may be reduced from c_o to a level c. If no investment in cost reduction occurs no change in marginal cost comes about. The higher the investment in cost reduction the lower is final unit cost, although cost reduction becomes

[22] Shavell (1979) pp 56-57.

progressively more difficult.[23] Hence

$$R(c_o) = 0 \qquad [2.1]$$

$$R'(c) < 0 \qquad [2.2]$$

$$R''(c) > 0 \qquad [2.3]$$

The instruments in a regulator's hands are prices, p, and lump sum transfers to the firm, T. Firms maximise profits, V, where,

$$V = (p-c)q(p) + T - R(c) \qquad [2.4]$$

The regulator's problem is one of constrained optimisation. In the command optimum he uses the instruments available to maximise the sum of consumer and producer surplus subject to the firm earning positive profits. The problem may be written in the following way.

$$\textit{maximise} \int_p^\infty q(x)\,dx + (p-c)\,q(p) - R(c)$$

subject to $V \geq 0$ [2.5]

Lump sum transfers, T, may be adjusted to ensure positive profits. Solving the above equation gives a social optimum where

$$p^* = c^* \qquad [2.6]$$

$$R(c^*) = T^* \qquad [2.7]$$

$$-R'(c^*) = q(p^*) \qquad [2.8]$$

[2.6] implies marginal cost pricing, [2.7] ensures the transfer just covers expenditure on cost reduction and

[23] The assumptions of identical demand conditions and homogeneous cost reduction technologies are later relaxed.

[2.8] is the condition for total cost minimisation to produce output q. Existence of a unique optimum is guaranteed by the following conditions.

$$-R'(c_o) < q(c_o) \qquad [2.9]$$

$$-R'(0) > q(0) \qquad [2.10]$$

$$-q''(c) - R''(c) < 0 \qquad [2.11]$$

These imply that cost reduction is initially cheap but then gets progressively costlier. The procedure followed is that the regulator announces his pricing rule, and establishes that he will set both prices and transfers on the basis of what he observes. Firms then invest in cost reduction, the regulator observes cost levels c, and cost reduction investment R(c). With this knowledge the regulator then sets prices and makes transfers according to the announced rule. Finally, firms produce output, sell it at the regulated price level and receive transfers.

The linchpin of the whole system, however, is the ability of the regulator to break the link between a firm's own cost level and the price it receives. This is done by determining price according to the cost levels of other firms. Taking the case of N identical firms, where $N \geq 2$, a firm i is assigned a 'shadow firm'. This shadow, or benchmark, firm has its unit cost level calculated as the mean marginal cost of all other firms. In addition the mean cost reducing expenditure for all other firms is calculated. Then the price permitted by the regulator is set equal to this shadow marginal cost, and the transfer (T) set equal to the mean cost-reducing expenditure. Shleifer shows that if firms find this scheme credible and choose cost levels accordingly not only will the social optimum, $c_i = c^*$, be achieved, but the equilibrium will be unique. The rule generalises; but its workings rest finally on the ability of the regulator,

> "...to commit himself not to pay attention to the firms' complaints and to be prepared to let the firms go bankrupt if they choose inefficient cost levels. Unless the regulator can credibly threaten to make inefficient firms lose money...cost reduction cannot be enforced."[24]

The model is extended in two ways. Firstly it is shown that compensation based on prices alone and not lump sum transfers is sufficient to permit the functioning of yardstick competition. Secondly the model may be adapted to cope with the problem of heterogeneity.

In the real world local monopolists serving separate markets seldom operate in identical environments. Heterogeneity is a characteristic of firms themselves and the markets they serve. The workings and conclusions of the models presented above are undermined by this fact and the price rule must be redefined in order to return the outcome to first best. Shleifer extended the analysis in the following way. Assume that firms differ in terms of their exogenous characteristics, θ. This heterogeneity, it is argued, may be corrected for by regressing costs on characteristics that determine the diversity. Thus, a new first-best solution is attained with costs $c(\theta)$, prices $p(\theta)$ and transfers $T(\theta)$ that satisfy the modified conditions for each type of firm θ,

$$-R_1\ (c,\theta) = q(p) \qquad [2.12]$$

$$c(\theta) = p(\theta) \qquad [2.13]$$

$$T(\theta) = R(c,\theta) \qquad [2.14]$$

Substituting [2.13] in [2.14] gives

$$-R_1\ (c,\theta) = q(c(\theta)) \qquad [2.15]$$

[24] Shleifer (1985) p323.

A Taylor approximation may be made of this around some point (θ_m , c_m (θ_m)), which may in turn be solved to give,

$$c \approx a + b\theta \qquad [2.16]$$

in which

$$a=\frac{c_m(R_{11}+q_1)+\theta_m R_{12}}{q_1+R_{11}} \qquad [2.17]$$

$$b=\frac{R_{12}}{q_1+R_{11}} \qquad [2.18]$$

where subscripts represent derivatives evaluated at (θ_m , c_m). Higher order Taylor expansions may be used, but Shleifer argues that [2.16] is in fact a good approximation for [2.15].

The regulatory system then works in a similar way to previously. The regulator estimates [2.16] using cost and other data on firm characteristics and commits himself to using the predicted unit cost level to set the price. If firms are identical as before, the system reduces to pure yardstick competition. The transfer, T, may be established in a similar way, using a Taylor expansion of $R(c,\theta)$ and running a regression to give an estimated R, the level of the transfer.

Two properties of the system accounting for heterogeneity may be noted. Firstly if [2.16] is an exact solution for [2.15] and if the list of exogenous characteristics, θ, is complete in every way the outcome in terms of unit cost is first best. Similarly, if the estimated R is in fact exact, then each firm breaks even in equilibrium. Nevertheless the outcome diverges from the optimum to the extent that the equation [2.16] is an approximation and leaves some heterogeneity unaccounted for. Two other potential sources of error are noted by the author. The first being that omitted exogenous characteristics must be uncorrelated with θ if omitted variable bias is to be avoided in the estimated coefficients. However this may not be problematic in practice if it may be assumed that the covariance between excluded and included characteristics is the same for all firms. If this is so, unbiased parameter estimates are not required and costs may be predicted consistently with the variables available. The second problem concerns the exogeneity of θ; where firms may have some control over their characteristics. Again the problem may not be insurmountable. In estimating the reduced form consistent predictions of costs may be obtained even if coefficient estimates are biased.

Overall then, a system of yardstick competition will lead to an efficient set of outcomes if firm heterogeneity is accounted for completely and correctly. The theoretical justification of this result is clear, but several criticisms may be levelled at the scheme.

Criticisms and Caveats.

The two main drawbacks of the system noted by Shleifer are its susceptibility to strategic manipulation and its inadequacy in dealing with heterogeneity. Larger numbers of competing firms are suggested for the first problem to ensure that cartels are more difficult to maintain. Heterogeneity is dealt with by regression analysis, although problems remain where not all factors are adequately accounted for. Waterson (1988) brings four more telling criticisms to bear.

The Shleifer analysis contains the assumption that the regulator has knowledge of the demand function facing the firm, q(p). Whilst this may be a close approximation to the truth for metered utility services such as electricity and gas, demand estimation is altogether more difficult in the case of unmetered goods such as water; or services subject to rapid technological change such as telecommunications. Another assumption is that the regression approach is a wholly adequate analytical device for picking up all relevant features determining costs. Clearly the assumption that every factor influencing cost reduction expenditure may be captured in this way is strong. Considerable cross sample variation may be omitted by the process.[25]

The model presented is confined to one period and the dynamics of the competitive process are unclear. Waterson (1988) notes that there is some implicit notion of a period over which current costs are gathered and fed into future actions although this is not made explicit. Furthermore, as Shleifer makes clear, the analysis critically rests on the assumption that the regulator is the only actor behaving strategically. Much scope remains for firms to collude explicitly or implicitly leading to a complete breakdown of the system. For yardstick competition to work it must be very strictly the case that those coming together to form each other's yardsticks are not allowed to collaborate in any way.

[25] See also Joskow and Schmalensee (1986) who say there is little yardstick competition in executive compensation schemes in the US electricity generation industry because so many factors lie outwith their control.

In terms of the practical implementation of the system authors such as Stelzer have cast doubt upon its effectiveness. Thus in the context of electricity regulation he notes,

> "First, it [the system of yardstick competition] is simply too weak and remote a goad to performance, especially as compared with more traditional, head to head competition. Second, as Landon has so tellingly demonstrated (1983), the problems of correcting cost data for differences beyond the control of management...are sufficiently daunting to make the range of error so wide, the cost comparisons so imperfect, that the authorities would not be able, sensibly, to order changes in prices on the basis of such shaky evidence alone."[26]

In other words, the problems of collusion and heterogeneity (noted by Shleifer) are considerable.

So whilst there appears to be a strong theoretical case for the use of yardstick competition in regulation, practically its implementation appears fraught with difficulties. These difficulties did not, however, prevent the system being adopted in modified form for the regulation of the privatised English and Welsh water and sewerage industry.

A Regulatory Device for the Water Industry.

From the beginning of the debate over privatisation of the English and Welsh Water Authorities, the key question in the minds of politicians was that of natural monopoly regulation. In an early written answer to Parliament the Prime Minister, Mrs Margaret Thatcher, stated,

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[26] Stelzer (1988) p69.

"...the Water Authorities are natural monopolies for many of their functions and we need to be particularly careful when considering replacing a public monopoly by a private one. Because of the environmental and public health responsibilities any proposal to privatise them would also raise issues of regulation." [27]

The question was singled out for attention by the Department of the Environment when, in October 1985, they commissioned Professor Stephen Littlechild to write a report on the economic regulation of water authorities. He confirmed their view of its importance, outlining what he considered to be the three main features of the industry with respect to regulation. First, the position of water as the natural monopoly 'par excellence'. The characteristic being derived from the networks of mains and sewers. Second, that the monopoly was permanent given the production processes involved. Therefore any regulation would be permanent. Third, that privatisation involved ten companies, not one, each with local monopoly power. It was this third point that proved crucial in shaping the regulatory solution. Littlechild suggested that Shleifer's yardstick competition could be applied to the industry. He wrote,

"Privatising ten authorities provides the opportunity to make regulation more effective in protecting consumers than it otherwise could be. It does so by making more information and instruments available to the regulator. He can make comparisons...He can use the performance of the water industry as a whole as a yardstick by which to assess the performance of each individual authority."[28]

The report noted the practical problems of controlling for heterogeneity and the importance of minimising strategic manipulation. Yardstick comparisons were consequently not

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[27] HC Debates, 31 January 1985, col 292w.

[28] Littlechild (1986) para 3.14.

the main means of regulatory control, but were to be only one of the regulatory levers.[29] The Government readily accepted the regulatory solution. For it offered a theoretically sound, imaginative and intuitively attractive answer to a very difficult question. The idea was taken up and applied in the discussions over the final privatisation settlement.

However, the evidence suggests that whilst the final regulatory settlement embraced the notion of yardstick competition, at the time of privatisation the system was not fully operable. Yardstick competition may have been the banner headline, but the regulatory story told underneath was very different.

The principal lever of control in the hands of the Regulator was a price cap: RPI + K. But not a price cap founded on any rigorous objective assessment of comparative unit costs. Rather a price cap fixed for individual companies after a political process of negotiation. Prices for a basket of charges were permitted to rise on average (in the charging year beginning in April) by the Retail Price Index (calculated in the previous November) plus a factor 'K' set for each company.[30] The initial K values were set by the Secretaries of State for the Environment and for Wales; those for the ten Water Authorities in August 1989, and those for the water only companies in spring 1990. Individual K settings represented assumptions made about capital expenditure and financing requirements,

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[29] In a later paper, Littlechild (1988) is very clear on this point. He states, "It is not claimed that the proposed scheme of regulation will fully replicate the workings of a perfectly competitive market. (Such a benchmark is scarcely relevant anyway, since there is no practical way of achieving it)." (p42)

[30] For details of the workings of the price cap see Ofwat Information Note No 8, revised February 1993.

as well as potential efficiency savings. The Office of Water Services (Ofwat) inherited the price cap limits and had to work with them.

It quickly became clear, however, that individual settings of K were rather generous. In the first few years following privatisation the companies as a whole recorded very large historic and current cost profits. The situation led the Regulator to seek voluntary reductions in water charges from nineteen of the thirty-two companies for the year 1993/4.[31] And whilst the interim adjustments may be attributed partly to the fall in construction prices brought on by recession, it may be argued that the Government erred on the side of caution when setting the original limits. Three reasons may be given for this. Firstly, the success of the privatisation issue depended on attracting a sufficient number of potential investors. By setting generous price limits profit forecasts were high and the issue, not unnaturally, was oversubscribed. Secondly, the success of the floatation depended crucially on the cooperation of the incumbent chairmen and managers of the Water Authorities. Such cooperation may have been enhanced through the use of a generous price caps. Thirdly there was considerable ignorance surrounding the comparative efficiency of companies. Government advisers resorted to assigning companies to an efficiency 'band' and felt unable to give a more precise assessment. Overall, it may be argued that the initial K settings owed only a little less to political manoeuvring than economic assessment of efficiency potential and investment needs.

But although the price cap, with its attendant provisions for interim and periodic adjustments, was initially set with scant regard to comparative efficiency measurement,

[31] Ofwat press release 25/92, 1st October 1992.

the principle of comparative or yardstick competition had not been abandoned. Shleifer's system required that these efficiency rankings would play the major part in the setting of the regulatory instrument; in this case the price cap. And although this did not take place in the initial post privatisation settlement the principle was not forgotten. Short term, a lack of technical expertise and adequate data combined with the political imperative to proceed quickly, ruled out the use of carefully prepared comparators. But the signs were there that the principle of yardstick competition had not been abandoned and would direct much future regulatory work.

Evidence for this may be found in the statutory provisions which amended UK competition policy for the privatised water industry.[32] Thus in connection with references made to the Monopolies and Mergers Commission (MMC) a new 'public interest' clause was added. Section 30 (3) of the Water Act 1989 stated,

> "In determining on a reference under section 29 [referral to the MMC] above whether any matter operates, or may be expected to operate, against the public interest the Monopolies Commission-(a) shall have regard to the desirability of giving effect to the principle that the number of water enterprises which are under independent control should not be reduced so as to prejudice the Director's ability, in carrying out his functions by virtue of this Act, to make comparisons between different such water enterprises."

Although Section 39 of the Competition and Service (Utilities) Act 1992 amended the provision, removing the

[32] The principal acts relating to the English and Welsh water industry since 1989 are: Water Act 1989 (ch 15), Water Industry Act 1991 (ch 56), Water Resources Act 1991 (ch 57), Water Consolidation (Consequential Provisions) Act 1991 (ch 60), Statutory Water Companies Act 1991 (ch 58) and the Competition and Service (Utilities) Act 1992 (ch 43).

reference to 'independent control'[33], the reference to 'comparisons' in relation to the public interest survived all subsequent amendments. In addition the 1992 Act strengthened the Regulator's hand in pursuit of his duties[34] to promote economy, efficiency and to facilitate competition. By this he was given powers to collect information with respect to the levels of overall performance of water and sewerage undertakers, for use in the comparison of performance.[35]

Working the System.

But it was not only in statute that the principles of yardstick competition were preserved. In his first statement on the operation of the new regulatory regime, Ian Byatt signalled Ofwat's intention to follow the same line.

> "My objective will be to achieve through regulation the same balance as would otherwise be achieved by competitive markets, aided by my ability to compare the performance of 39 separate appointed companies....Because of the limited scope for direct competition, I will compare the performance of the appointed companies. In particular I will compare their costs, their efficiency and their return on capital." [36]

The point was reiterated in Ofwat's first annual report, which gave a very clear description of the whole process of yardstick, or comparative, competition.

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[33] Permitting a more permissive stance with respect to takeover and merger policy.

[34] The duties of the Regulator are laid out in Section 2 of the Water Industry Act 1991.

[35] Competition and Service (Utilities) Act 1992 s27 and s31.

[36] Statement by Director General of Water Services on the operation of the regulatory regime, Ofwat, 8/8/89, paragraph 6.

> "I shall compare the performance of the 39 appointed companies and use the examples of the best to set standards for the others to introduce an element of comparative competition. Such comparisons will cover material differences in operating cost, capital cost, levels of service and "customer care". There will be allowances for differences, such as geographical conditions, which are outside the control of efficient managements. These comparisons will help me to achieve a better deal for all water customers in England and Wales."[37]

Yet although yardstick competition was one goal of the new regulatory agency, the technical tools that the Regulator had at his disposal were initially not equal to the task. This was recognised and Byatt was at pains to make clear that any comparisons made were merely indicative of relative efficiency. All communications emanating from Ofwat stated that any final regulatory decisions would not be based on these comparisons.[38] Nevertheless work began on the development of suitable comparators in cooperation with the industry. This work was not focused on the attainment of some ideal set of comparators, but on the process of improving those that already existed and developing new techniques.

Initially the Charges Control Division of Ofwat was given responsibility for developing comparative competition and carrying out efficiency studies.[39] Within the division a 'Comparative Competition' section was created; headed by Jonathon Price. One of the early problems faced by the section was the lack of data on the operations of companies in the industry in sufficient quantity and of sufficient quality. Without reliable information any comparisons would be misleading. Consequently an early priority for the

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[37] Ofwat Annual Report 1989, p11.

[38] Ofwat Annual Report 1990, p37.

[39] Ofwat Annual Report 1989, p13.

Engineering Intelligence division of Ofwat was the setting up of information and reporting systems that would provide the basis for effective monitoring of companies. The importance given to this aspect of the work was emphasised in the 1990 Annual Report which stated,

> "Ofwat's strategy for regulatory reporting has been based on three tenets...(2) Need for comparable information." [40]

Parallel work on the use to which this improved data would be put, was carried out under the auspices of the Charges Control Division. A starting point for this work was given in a report prepared for Ofwat by KPMG Peat Marwick Mclintock and published in September 1990. A 'Comparative Efficiency Studies Working Group' (later known as the Comparative Performance Technical Group) was established; which in turn lead to the formation of subgroups. These subgroups reported back to the main Group on issues such as ratio analysis, activity costing and explanatcry factors. Progress reports and details of pilot studies undertaken by the main Group were reported in a series of 'Dear Finance Director' (Dear FD) letters which were distributed widely throughout the industry.[41] Industry representatives were invited to contribute to the work by submitting written responses to these letters as well as participating in workshops. There was a significant level of consultation between the industry and Ofwat at all stages in the process.

Steady progress was made: initially in the general acceptance of a modified system of yardstick competition by the industry. This lead Byatt to comment in the 1990 Ofwat

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[40] Ofwat Annual Report 1990, p36.

[41] See especially 'Dear FD' 19, 22, 33, 38, 41, 49.

annual report,

> "There is an acceptance of the value and importance of comparative competition in the water industry. There is also recognition that any reduction in the number of comparators would be prejudicial to my ability to compare performance and so to customers in general." [42]

Once accepted in principle the next stage of the process was the publication of comparative statistics. On this Ofwat proceeded in stages, starting with non-attributable information but announcing its firm intention to publish more detailed figures in following reports. For example, the 1989/90 report on levels of service[43] contained non-attributable information leaving the decision to publish more detailed statistics by company area to the individual firms. By 1990/1 there was a formal requirement for companies to report on levels of service to their customers. The first attributable information on the volume of water delivered by individual companies and the unit costs of that water was published by Ofwat in November 1992[44], based on information gathered via the 1992 July Return. Other publications have followed; widening the scope of detailed industry data in the public domain. These publications have continued to attract a large amount of publicity and press attention. The introduction of comparative statistics has been a steady but unrelenting process.

The Regulator appears optimistic in relation to the progress achieved so far and the continuing development of

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[42] Ofwat Annual Report 1990, p8.

[43] 'The Water Industry in England and Wales - Levels of Service Information 1989/90', Ofwat, Birmingham, October 1990.

[44] 'The Cost of Water Delivered to Customers 1991-92', Ofwat, Birmingham, November 1992.

this aspect of his work. The 1991 Annual Report summed up the position in the following way,

> "The new structure of the industry has provided a powerful stimulus for taking forward work on all aspects of the appropriate comparisons. It is essential for all companies to provide the cost numerators, quality and quantity denominators and such explanatory factors as are necessary in a common format and to consistently applied definitions. Good progress has been made demonstrating the success of the technical working group approach that Ofwat has developed with the industry."[45]

As if to confirm this optimism it may be noted that in preparation for the 1994/5 periodic review one of the six projects being undertaken by Ofwat is titled 'Comparative Performance'. Using the experience acquired since privatisation the project's aims include the development of methods of comparing cost-efficiency between companies and looking at how such comparisons could be incorporated into the periodic reviews. Given the evidence presented above it is to be expected that the weight given to evidence from comparative efficiency studies will be greater in the 1994/5 price cap review than at the initial 1989 settlement. The development of reliable comparators continues; meanwhile the Regulator has signalled his intention to continue work in the direction of a workable system of yardstick competition; and to rely more heavily on the results for future price cap reviews.

7. Conclusion.

In the space of just over four years the principle of yardstick competition has been taken up and applied to regulation of the English and Welsh water industry. Whilst not being as fully developed as the Government had expected and Littlechild had suggested at the time of privatisation,

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[45] Ofwat Annual Report 1991, p50.

the present regulatory regime does bear the unmistakeable hallmarks of Shleifer's original system.

The discussion has, however, raised some important questions. Aside from the central question as to whether yardstick competition can work, subsidiary questions include: why has the Regulator drawn back from the use of the term 'yardstick competition' in all communications, preferring the phrase 'comparative competition'?; whilst the Regulator may be optimistic about comparative competition, does the industry share this enthusiasm?; what are the views of company officials on the workings of the system?; do they regard it as an attainable long term goal or do they believe the initiative has run its course?; to what extent does the operation of the Regulatory regime inhibit collusion? Answers to these questions may be found in qualitative rather than quantitative evidence. Evidence gathered and presented in Chapter 7. For the moment we content ourselves with a technical question.

The outstanding practical problem lies in the ability of the regulator to control for company heterogeneity in comparative efficiency measurement. And whilst considerable progress on this question has been made by the Comparative Performance Technical Group of Ofwat, the issue is as yet unresolved. The matter is of great importance, for the inability adequately to account for heterogeneity was first pointed up by Shleifer (1985) as a fatal flaw in the system. Very limited econometric work has been carried out to date, yet regression techniques have great potential in controlling for company heterogeneity. In tackling the problem two theoretical points made above work in our favour. Firstly, Shleifer explicitly notes that regression techniques may be appropriate. Secondly, the point made jointly by Shavell and Holmstrom that additional information, despite its imperfections will lead to the attainment of a superior regulatory outcome. Indeed, Holmstrom cites the use of cost accounting and similar information systems as being useful for the task. Therefore a perfect comparison of company efficiency, even if attainable, would not be necessary. Imperfect comparisons of efficiency will improve the outcome.

The following three chapters address this technical issue: the linchpin of yardstick competition. A system of comparative efficiency measurement (necessarily rather imperfect) using econometric techniques is developed and implemented with conclusions being drawn as to its applicability in the context of the industry.

Chapter 3.

Modelling: Theory and Evidence.

Introduction.

It has been argued that the question of comparative efficiency measurement is the outstanding technical issue facing a regulator seeking to implement a system of yardstick competition. Furthermore, the originator of the theory itself has highlighted regression techniques as appropriate tools for the task. Finally, the context in which the question is set is the water and sewerage industry in England and Wales. These three points supply the motivation, technical apparatus and context for the following three chapters. Given the technical problem and the tools available, how should we proceed? We begin by considering briefly the context in which we are operating empirically: namely the water and sewerage industry in England and Wales.

All companies operating in the industry are charged with meeting the reasonable demands of customers in their area. In other words, from the point of view of the supplier, output is an exogenous variable in the production decision. In addition, firms may be assumed to be price takers in factor markets, and to behave in such a way as to minimise costs.[46] These assumptions imply that a cost function reflecting the endogeneity of factor quantities and cost minimising behaviour is an appropriate technical device for the study. But what are the properties of the cost function and how may it be employed in empirical work?

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[46] These behavioural assumptions have been made by many authors such as Feigenbaum and Teeples (1983) and Crain and Zardkoohi (1978).

Cost Function Specification.

The traditional point of departure for neoclassical production theory is the representation of a set of physical and technological possibilities by a production or transformation function. Restrictions on a general functional representation are derived from behavioural, often optimising, assumptions about the firm. In empirical work all a priori information concerning a firm's technological and economic environment is employed in constructing a representation of the production decision. Justification for the imposition of theoretically valid restrictions is made on the grounds of improved efficiency of the empirical estimates.

The insights of duality theory have informed more recent work. It is postulated that because the technological environment constrains the optimising behaviour of firms , an accurate representation of optimising behaviour may be used to study the technology. Similarly, since technology conditions a producer's response to market phenomena, an examination of this conditioned response will enable conclusions to be drawn about the underlying technology. Thus a cost function, embodying the consequences of cost minimising behaviour by the producer , and a production function, embodying production efficiency on the part of the producer, are equally fundamental descriptions of production technology.

A basic paradigm of neoclassical economics concerns a firm facing fixed technological possibilities and competitive input markets, choosing an input bundle to minimise the cost of producing a given level of output.[47] With fixed input prices minimum cost is determined as a function of

[47] The water industry may be modelled in this way.

output. Relaxation of this restriction means both input prices and output enter as arguments in the cost function. The cost function's power as an analytic tool also derives from its computationally simple relation to cost minimising input demand functions. Thus the function's partial derivatives with respect to input prices give the input demand functions, and the sum of the input demands multiplied by price equal costs.

An early analysis of the properties of the cost function's price derivatives may be traced to Hotelling (1935) who presented the mathematically equivalent problem of minimising consumer spending subject to a utility constraint. However, the complete characterisation of cost-minimising behaviour by the cost function was outlined by Samuelson (1947) and rigorously developed in Shephard's (1953) classic exposition of duality.

In a later work McFadden (1978) noted that this duality,

> "establishes the cost function as a 'sufficient statistic' for all economically relevant characteristics of the underlying technology."[48]

Consequently the cost function provides a natural basis for the investigation of a producer's technological and economic environment. It may be represented in algebraic form as follows.

Following the terminology of McFadden (1978), consider a firm using N inputs (n=1,2...N) to produce M outputs (m=1,2,...M), with a vector of factor input quantities $\underline{v}$, a non negative input price vector $\underline{w}$, and a non negative output vector $\underline{y}$. Let Y represent the production possibility set of the firm, ie the technologically constrained set of input output pairs $(\underline{v},\underline{y})$, assumed to be non empty, closed

[48] McFadden (1978) p4

and requiring a non zero input bundle to produce a non zero output bundle. Now define Y* as the producible output set where:

$$Y^* = \{\underline{y} \mid (\underline{v},\underline{y}) \in Y \text{ for some } \underline{v}\} \qquad [3.1]$$

for each $\underline{y}$ in Y* let $V(\underline{y})$ be the input requirement set containing all the input bundles $\underline{v}$ which can produce $\underline{y}$. Thus:

$$V(\underline{y}) = \{\underline{v} \mid (\underline{v},\underline{y}) \in Y\} \qquad [3.2]$$

McFadden (1978) defines an 'input regular' production possibility set Y in which Y* is non empty, $V(\underline{y})$ is closed for each $\underline{y}$ in the set of producible outputs, and the non zero output bundle does not contain the zero input bundle.

The mathematical representation of the cost minimising problem follows directly. Assume a firm has an input regular production possibility set, a producible output set Y* and input requirement sets $V(\underline{y})$ for $\underline{y}$ in Y* . With competitive input markets, a strictly positive price vector $\underline{w}$ and the firm choosing inputs $\underline{v}$ to minimise the cost of producing output $\underline{y}$, the cost function may be written:

$$c=C(\underline{y},\underline{w})=\min \{\underline{w}.\underline{v} \mid \underline{v} \in V(\underline{y})\} \qquad [3.3]$$

The cost function may be shown to exist for positive $\underline{w}$ and all $\underline{y}$ in the output set, employing the mathematical result that a continuous function achieves a minimum on a non empty, closed, bounded set. A formal presentation of this result and derivation of the function's properties may be found summarised in McFadden (1978). In the present context a rather brief, informal statement of the cost function's properties is sufficient to inform the discussion. Thus a differentiable cost function $C(\underline{y},\underline{w})$ is assumed to exist which is: nonnegative, linearly homogeneous in input prices $\underline{w}$ for each fixed output level, nondecreasing in $\underline{w}$ for fixed $\underline{y}$, concave in $\underline{w}$ for fixed $\underline{y}$, nondecreasing in $\underline{y}$ for fixed $\underline{w}$ and continuous from below in $\underline{y}$ for fixed $\underline{y}$.[49] Notable is the positive linear homogeneity property, which embodies the principle that only relative prices enter the economic calculus of optimising agents. Consequently, as long as input prices vary proportionately, the cost minimising choice of inputs will not vary.

Hedonic Cost Functions.

Whilst the specification of the neoclassical cost function outlined above has proved to be a robust foundation for much empirical work, one way in which it has recently been enriched is through the application of the insights of hedonic price analysis. This extension is of particular relevance to the water industry as will be made clear later.

The hedonic approach centres on the explicit adjustment of price and quantity indices for variation in quality and technology over time. The technique may be traced to the work of Court (1939)[50] who constructed a set of quality adjusted price indices for the US manufacturer General Motors. In this he aimed at isolating a pure price effect adjusted for quality variation over time. His significant methodological contribution was the hedonic regression equation, serving as the means whereby price index

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[49] A fuller discussion of the properties may be found in Chambers (1988) chapters 2 and 3

[50] Waugh (1928) made an important early contribution in a study examining the extent to which commodity price variation reflected quality differentials.

estimates could be adjusted for quality change. The Court (1939) hedonic hypothesis framed heterogeneous goods as aggregates of their characteristics ie qualities. Thus regression analysis enabled implicit marginal prices to be calculated as derivatives of the hedonic price equation with respect to the levels of the characteristics.

Two decades later, Griliches (1961) revived interest in the hedonic approach. Whilst the Court analysis of hedonic prices had focused on the demand side, later research envisaged hedonic prices as the outcome of shifting supply and demand curves for characteristics.[51] In addition, hedonic insights were applied to cost and production function specifications.

This adjustment of price indices for quality differentials has a parallel in cost function specification. Namely, the adjustment of generic output for quality differentials, explicitly incorporating variation in output quality and exogenous technical conditions. An intuitive rationale appeals to the notion that, when physical output varies with respect to quality or other attributes, these should be taken into account in the estimation of the cost function. From a technological and econometric standpoint, the broader issue is whether quality adjustment should be effected through regarding the firms as producing multiple outputs or generic outputs with variable qualities.

Conventionally, quality differences have been accounted for by specifying multiple outputs for a firm or industry. Multiproduct cost function specifications permit a rich analysis of the effects on costs and factor demands of the changes in composition and level of output. Recent work

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[51] A more recent influential study was undertaken by Chow (1967).

includes research by Caves, Christensen and Tretheway (1981), Cowing and Holtmann (1983) and Chiang and Friedlaender (1985). This approach, however, suffers two main drawbacks. First, the multiple output vector quickly becomes unwieldy and problematic for econometric estimation. Second, the approach is appropriate to the case of products with well defined qualities (eg microwave ovens), but inappropriate for commodities exhibiting a continuum of qualities (eg water supply). If quality is truly continuous there is no convenient way to define quality specific output. Water is a prime example.

Several water companies producing an identical quantity of water each year are unable to guarantee identical quality. Potable water is a surprisingly heterogeneous product with quality determined, in part, by source and treatment. Other attributes of output include the nature of the area served, rainfall pattern and distribution system employed. Thus a simple measure of generic output would fail to capture the true relationship between cost and output. Rather than treat specific quality levels as separate goods, effective output may be specified as a function of a generic measure of physical output (eg megalitres of water supplied per day) and the qualities of the physical output (eg index of treatment, density of population served). Hence, hedonic functions of outputs and qualities enter as arguments in the cost function.

The advantages of the hedonic approach now become clear. Primarily, improved specification derives from taking output characteristics into account. Spady and Friedlaender (1978) presented econometric evidence to confirm this assertion. In their examination of a hedonic cost function for the US regulated trucking industry, they showed that conclusions regarding potential economies of scale and factor demands differed fundamentally between nonhedonic and hedonic specifications. The hedonic specification was preferred. Secondly it permits the representation of a class of technologies unrestricted in quality - quantity combination. Finally, it avoids the restrictive assumptions required for hedonic inflation which are unlikely to hold in noncompetitive cases.[52]

Hedonic Cost Function Specification.

The hedonic extension of the neoclassical cost function may be developed in the following way, following Spady (1979). Let $\underline{y}$ represent the generic output vector and $\underline{q}$ a vector of qualities; with q_i the qualities associated with the generic output y_i. Restricting each quality to be associated with only one output, variables $z_i=[y_i,q_i]$ may be defined, with vector $\underline{z}=([y_1,q_1],\ldots,[y_m,q_m])$. The cost function may be rewritten:

$$C(\underline{y},\underline{q},\underline{w}) = C\ (\phi_1(y_1,q_1),\ldots,\phi_m(y_m,q_m),\underline{w}) \qquad [3.4]$$

$$\text{or} \quad C(\underline{z},\underline{w}) = C\ (\phi_1(z_1),\ldots,\phi_m(z_m),\underline{w}) \qquad [3.5]$$

The expressions imply:

$$\frac{\delta}{\delta w}\left[\frac{C_z^{i_j}}{C_z^{i_k}}\right]=\frac{\delta}{\delta z}\left[\frac{C_z^{i_j}}{C_z^{i_k}}\right]=0 \qquad [3.6]$$

$i = 1\ldots m$

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[52] Spady and Friedlaender (1978) p160 highlight the problem of hedonic inflation. The conventional approach of utilising a quality adjusted price in obtaining a deflated output measure assumes quality combinations with identical input requirements are sold at identical prices. They argue that this is highly unlikely in a government regulated industry where certain quality combinations must be produced and sold at mandated prices.

where Cz^{i}_{j} is the partial derivative of C with respect to the jth component of z_i and $i \neq 1$.

The above equivalence of partial derivatives is an expression of the Leontief (1947) aggregation conditions corresponding to the previous pair of equations. $\phi_i(.)$ represents the aggregator function, the channel through which the elements of z_i are aggregated to one output. It is assumed that the continuum of different 'quality' measures of the physical output can be consistently aggregated by ϕ_i (.). Spady (1979) interprets this in the following way,

> "the interpretation of [equivalence of partial derivatives] in conventional aggregation theory is that marginal rates of transformation (marginal cost ratios) between components of an aggregate are independent of factor prices, technological conditions, and outputs not in the aggregate. Thus the mix of outputs within an aggregate does not affect optimal factor intensities, and technological conditions do not affect the (component) output combinations feasible at a given level of the aggregate."[53]

The general specification $C= C\ (\phi(\underline{z}),\underline{w})$ is a quality separable hedonic cost function. Although being one of the most parsimonious forms to take account of quality differentials, quality separability implies the various restrictive assumptions noted above by Spady (1979). In particular, service characteristics are assumed to have no effect on factor intensities, technological conditions do not affect feasible generic output/quality combinations and factor prices are independent of marginal cost ratios between two different (y_i,q_i) combinations. In terms of water supplied, quality separability implies that the prices of labour or capital do not affect the combinations of highly treated, urban supplied water that can be produced at equal cost with rural supplied water

[53] Spady (1979) p14.

possessing other attributes. The property is required, nevertheless, if unambiguous quantity comparisons of the outputs of different firms are to be made.

One further conventional restriction may be applied through aggregation. Namely that $\phi_i(y_i, q_i)$ be homogeneous of degree one in y. This is convenient and intuitively attractive in the case of the water supply industry. Homogeneity of degree one in the generic quantity implies that a doubling of physical output at a given quality level doubles the measure of output. Thus a specification equivalent to the "simple repackaging" model employed by Fisher and Shell (1971) in the context of price indices is used:

$$\phi_i(y_i, q_i) = y_i . f(q_{i1}, \ldots, q_{ir}) \qquad [3.7]$$

In the 'repackaging' case a quality improvement is exactly equivalent to obtaining a larger package of the old good at the same price, or paying less per unit for the old good. No further restrictions need be placed on f(.) but for convenience, simplicity of interpretation and economy of parameters f(q) will be taken as a simple Cobb-Douglas function.[54] Rosen (1974) raises the problem of identification in connection with f(.). Caution is recommended in interpreting hedonic coefficients as reflecting either cost or demand effects, because hedonic functions usually represent a reduced form of the supply-demand equilibrium. The estimated cost function may not give an unambiguous description of technology if f(.) is endogenous to the firm. In the case of the water supply

[54] Spady (1979) p14-15 notes that interpreting z_i as generic output and corresponding quality yields a model equivalent to that of Fisher and Shell (1971) in the context of price indices. The model used is simple repackaging.
$\phi_i(y_i, q_i) = y_i . f_i(q_i)$
ie water is 'packaged' in megalitres per day and the service content of the package is a function of the characteristics of the quantity ie length of mains etc

industry the problem may be set aside as the quality characteristics are largely exogenous. Each water company has responsibility for supply within a specified area; clearly rainfall, water abstraction and supply decisions are outwith the immediate control of the firm. Therefore it appears reasonable to interpret the hedonic coefficients in the cost function as representations of technology.

Transcendental Logarithmic Cost Function.

Given this theoretical background the next question is what particular functional form to adopt in the empirical work? A popular choice among econometricians, and one that is followed here is the transcendental logarithmic (translog) form of Christensen, Jorgenson and Lau (1973). This functional form may be envisaged as a second order Taylor series approximation in natural logarithms to an arbitrary (cost) function.

The unrestricted, nonhomothetic translog cost function may be written:

$$\ln C = \alpha_o + \alpha_y \ln Y + \tfrac{1}{2}\alpha_{yy}(\ln Y)^2 + \Sigma_i \alpha_i \ln w_i + \tfrac{1}{2}\Sigma_i \Sigma_j \gamma_{ij} \ln w_i \ln w_j + \Sigma_i \gamma_{yi} \ln Y \ln w_i. \qquad [3.8]$$

Where $\gamma_{ij} = \gamma_{ji}$

C = cost

w_i, w_j = input prices

Y = Output

α_o, α_y, α_{yy}, γ_{ij}, γ_{yi} = parameters

The function may be specified for McFadden's (1978)[55] version of a cost function containing an argument representing 'technological conditions 't', C(y,w,;t) thus:

$$\ln C = \alpha_o + \alpha_y \ln Y + \Sigma_i \alpha_i \ln w_i + \Sigma_t \alpha_t \ln t + \tfrac{1}{2}\alpha_{yy}(\ln Y)^2 + \tfrac{1}{2}\Sigma_i \Sigma_j \gamma_{ij} \ln w_i \ln w_j + \Sigma_i \gamma_{yi} \ln Y \ln w_i + \tfrac{1}{2}\Sigma_t \Sigma_s \alpha_{ts} \ln t_t \ln t_s + \Sigma_s \Sigma_i \alpha_{is} \ln w_i \ln t_s + \Sigma_t \alpha_{yt} \ln Y \ln t \qquad [3.9]$$

Where t = technological' conditions.

Criteria for the adoption of this functional specification were suggested, informally, by Diewert (1971) and amplified in later contributions. The translog form benefits from a specification which is general, flexible, parsimonious, linear and consistent.

The generality of the nonhomothetic cost function derives from the independence of input demands from the level of output. If a function has a sufficient number of free parameters to be able to provide a second order approximation to an arbitrary twice continuously differentiable function it is 'flexible' in the Diewert (1974) sense. Fuss, McFadden and Mundlak (1978) label a functional form 'parsimonious' if it has the minimal number of free parameters required to maintain flexibility. Linearity in parameters is an econometric convenience, and consistency with the theoretical properties of cost

[55] If quality separability is an unacceptable assumption, use may be made of the neoclassical cost function extension noted by Spady (1979) as due to McFadden (1978). The cost function may be respecified as C=C(y,w;t) where t represents technological conditions; which may be taken to include service characteristics.

functions an empirical imperative.[56] The translog function satisfies all these criteria, and consequently has been widely used in cost and production studies.[57]

However, parameter restrictions must be imposed on the translog specification to ensure certain regularity conditions are met. Primarily, homogeneity of degree one in input prices, given output, is imposed. The restrictions are:

$$\Sigma_i \alpha_i = 1, \qquad \Sigma_i \gamma_{ij} = \Sigma_j \gamma_{ji} = \Sigma_i \gamma_{iy} = 0.$$

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[56] Lau (1974) has distinguished two concepts of approximation both satisfied by the translog function. The following is taken directly from Spady (1979).
In the first, a function H(z) provides a second order differential approximation to G(z) at z_o providing $H(z_o) = G(z_o)$ and:

$$\frac{\delta H}{\delta z}\Big|_{z=z_o} = \frac{\delta G}{\delta z}\Big|_{z=z_o}$$

$$\left[\frac{\delta^2 H}{\delta z_i \delta z_j}\right]_{z=z_o} = \left[\frac{\delta^2 G}{\delta z_i \delta z_j}\right]_{z=z_o}$$

Secondly, H(z) provides a second order numerical approximation to G(z) at z_o if $H(z_o) = G(z_o)$ and:

$$|H(z)-G(z)| \leq \frac{k\|z-z_o\|^3}{\|z_o\|^3}$$

For all z in a given neighbourhood of z_o. Where $\|z\|$ is the norm of z and k is a constant depending on z_o. Thus any function H(z) that can be interpreted as a second order Taylor Series approximation to G(z) around z_o is a numerical and differential approximation. The translog cost function as written can be viewed as the Taylor expansion around the point (1,1,1,..1) and ln1=0. The point of approximation may be envisaged as a hypothetical firm with arguments in its cost function equivalent to the sample arithmetic means.

[57] For example see Christensen and Greene (1976) and Feigenbaum and Teeples (1983). Chambers (1988) presents a full discussion of this.

The 'technological variable' adds $\Sigma_i \alpha_{it} = 0$

Linear homogeneity implies that, for a fixed level of output, total cost must increase proportionately when all prices increase proportionately.

Additional parameter restrictions may be imposed on the function corresponding to further restrictions on the underlying technology. Beginning with the most general specification, assumptions of homotheticity, homogeneity, and unitary elasticity of substitution may be made. Following the above notation, parameter restrictions for the various assumptions are as follows:

homogeneity of degree one in input prices (always applied);

$$\Sigma_i \alpha_i = 1, \qquad \Sigma_i \gamma_{ij} = \Sigma_j \gamma_{ji} = \Sigma_i \gamma_{iy} = 0.$$

homotheticity;

$$\gamma_{yi} = 0$$

homogeneity;

$$\gamma_{yi} = 0 \text{ and } \gamma_{yy} = 0$$

unrestricted translog with unitary elasticity of substitution;

$$\gamma_{ij} = 0$$

homotheticity and unitary elasticity of substitution;

$$\gamma_{yi} = 0 \text{ and } \gamma_{ij} = 0$$

homogeneity and unitary elasticity of substitution(Cobb Douglas).

$$\gamma_{yi} = 0 \quad \gamma_{yy} = 0 \quad \gamma_{ij} = 0$$

Subsequent analysis of the results must be made with reference to underlying theory. In this context, it is to be noted that the translog function has been interpreted as a Taylor approximation in first and second derivatives; with the corollary that the properties of the underlying function are inherited by the approximating function only at a single point. For some properties, eg homogeneity and symmetry, satisfaction at the point implies that the property applies globally. Concavity, however, cannot hold globally for any translog function (unless it reduces to Cobb Douglas) as no combination of restrictions will guarantee global negative semi-definiteness of the Hessian. This is a significant limitation, for concavity in the vector of input prices is an important property of any cost function. Consequently, the analysis and interpretation of empirical results must include explicit consideration of their global or local applicability; bearing in mind that the translog function remains an approximation, and not an exact representation of a cost function throughout the conceivable range of its arguments.[58]

Frontier Cost Functions: Development.

Although the theoretical apparatus discussed above underpinned much empirical work concerned with comparative efficiency measurement, one further technical development should be noted. This development was the econometric estimation of so-called 'frontier' production, cost and profit functions.

The idea of the frontier is simple, and completely consistent with the underlying economic theory of optimising behaviour. A cost frontier comprises the locus of points corresponding to the minimum cost of producing a given level of output. (Production and profit frontiers may be drawn in a similar way) Therefore any deviations from the frontier may be interpreted as measures of

[58] The cost function, however, has the convenient feature that derived demand functions for the factors of production can be easily computed. Shephard (1953) investigated this property in the context of duality.

inefficiency.

Although straightforward in theory, the practical construction of frontiers proved to be a challenging problem: two competing paradigms emerged. The first was the mathematical programming approach, exemplified in the technique of Data Envelopment Analysis (DEA). With its origins in the work of Farrell (1957), this had the advantage of not explicitly imposing any one functional form on the data. It did however suffer from the fact that the frontier could be warped or pulled out of shape by observations contaminated by statistical 'noise'.[59] The second was the econometric approach whereby frontiers were fitted using regression techniques. This had the advantage of being able to handle statistical noise, but did impose an explicit and restrictive functional form for the technology. It is this latter technique that will be examined more closely

Pioneering work on the econometric approach to frontier function estimation was carried out by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). They postulated a parametric representation of technology with an error term composed of two parts: a two sided 'noise' component and a one-sided 'efficiency' term. This advanced earlier work on frontier regression models by Aigner and Chu (1968), who considered deterministic frontier models in which error terms were constrained to be one sided. These 'stochastic frontiers' were constructed for cost, production and profit functions and had the following general form. Consider, for example, a stochastic cost frontier,

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[59] Recent developments in the mathematical programming approach have been discussed by Seiford and Thrall (1990).

$$\ln C_i = \ln C(\underline{y}_i, \underline{w}_i) + u_i + v_i \qquad [3.10]$$

where C represents cost, $\underline{y}_i$ the output vector, $\underline{w}_i$ the input price vector, u_i the one-sided disturbance and v_i the two-sided disturbance. The error term $u_i + v_i$ is in two parts. v_i is the two sided component capturing random shocks and statistical noise and is generally assumed to follow a normal distribution. u_i is the one-sided component reflecting inefficiency, which in the case of the cost frontier is non-negative. As to its distribution Aigner, Lovell and Schmidt (1977) proposed the half-normal and exponential distributions; Stevenson (1980) proposed the truncated normal and Greene (1990) the two-parameter gamma.

In empirical work the Aigner, Lovell and Schmidt (1977) assumptions have been followed widely, giving:

$$v_i \sim N(0, \sigma_v^2)$$
$$u_i \sim |N(0, \sigma_u^2)|$$

and a likelihood function:

$$lnL = \frac{N}{2}\ln\left(\frac{2}{\Pi}\right) - N\ln\sigma + \sum_{i=1}^{N} \ln\left[1 - \Phi\left(-\varepsilon_i \frac{\lambda}{\sigma}\right)\right] - \frac{1}{2\sigma^2}\sum_{i=1}^{N} \varepsilon_i^2$$

[3.11]

where N represents the number of observations, Φ (.) the standard normal distribution function and where other terms are calculated in the following way.

$$\epsilon_i = u_i + v_i \qquad [3.12]$$
$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \qquad [3.13]$$
$$\lambda = \sigma_u / \sigma_v \qquad [3.14]$$

The function may be estimated by maximum likelihood methods or corrected ordinary least squares (COLS). This gives information on average or mean technical inefficiency. Hence overall technical inefficiency may be written as:

$$\sigma_u\sqrt{\frac{2}{\pi}}$$

[3.15]

where,

$$\sigma_u=\frac{\lambda\sigma}{\sqrt{1+\lambda^2}}, \sigma_v=\sqrt{\frac{\sigma^2}{1+\lambda^2}}$$

[3.16]

Nevertheless this leaves the problem of the calculation of inefficiency for individual observations. Jondrow, Lovell, Materov and Schmidt (1982) tackled the problem and suggested a means whereby observation-specific estimates of inefficiency could be derived. Their solution used the distribution of the inefficiency term conditional on the estimate of the entire composed error term, ie the expected value of u_i given the value of the composite error.

The expected value and mode are given as follows:
Expected value:

$$E(u|\varepsilon)=\sqrt{\frac{\sigma_u^2\sigma_v^2}{\sigma^2}}\left[\frac{\phi(\frac{\varepsilon\lambda}{\sigma})}{1-\Phi(\frac{\varepsilon\lambda}{\sigma})}-(\frac{\varepsilon\lambda}{\sigma})\right]$$

[3.17]

Mode:

$$M(u|\varepsilon)=\varepsilon\,(\frac{\sigma_u^2}{\sigma^2})$$

[3.18]

if $\epsilon \geq 0$
$= 0$ if $\epsilon < 0$

where ϕ represents the standard normal density function.[60]

But whilst this was a significant advance, not all proved to be pure gain. The estimates themselves are not consistent estimates of u, since the variability of the conditional distribution u given ϵ is independent of sample size. In addition, whilst it is good to have observation-specific estimates of inefficiency, the price of the advances is that one must impose specific distributional assumptions on both noise and inefficiency terms. These and other issues are discussed at greater length in an excellent review of the literature by Bauer (1990).

The methods of frontier function estimation continue to be developed. Recent advances in this area include the extension of estimation techniques to whole systems of cost equations and frontier function estimation using panel data. The latter will be taken up again later; but among the leading proponents of the approach are Pitt and Lee (1981), Schmidt and Sickles (1984), Battesse and Coelli (1988), Cornwell, Schmidt and Sickles (1990) and Kumbhakar (1990). Meanwhile other problems remain. They include the problems of dealing with the non-independence of inefficiency and regressors, the sensitivity of results to stochastic assumptions and the detailed examination of the

[60] Values for the exponential case are also given.

relationship between technical and allocative efficiency.[61]

Modelling Producer Behaviour in the Water Industry: A Survey.

Having laid the theoretical foundations we now turn to the empirical analysis. But before proceeding a brief examination of the development of the econometric modelling of producer behaviour in the water industry will be undertaken. Not only will this set the analysis in its proper historic and literary context, but it will also survey ways in which the question of comparative efficiency measurement has been addressed in the past for this particular industry.

Early empirical work modelling producer behaviour drew its motivation, in part, from efforts to explain average labour productivity; and to quantify relationships between inputs and outputs in agriculture. This led to conclusions being drawn regarding the estimation of returns to scale and substitution elasticities among inputs. An early discussion of the notion of the production function may be found in the 1890 edition of Marshall's 'Principles' which devoted considerable attention to the theoretical relationships among production functions and factor demands. Later, applied work on production and cost was undertaken by Cobb and Douglas (1928) in their attempt to test the theory of marginal productivity using annual data 1899-1922 assuming constant returns to scale. Walters (1963) gives a comprehensive survey of this early empirical literature.

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[61] Schmidt and Lovell (1980) have done work in this area.

However, it was the introduction of more generalised yet empirically implementable functional forms, the insights of duality theory and the rapid development of computer facilities that lead to renewed interest in the area in the late 1960's. Specifically, the work of Christensen, Jorgenson and Lau (1971) on the general transcendental logarithmic functional form precipitated a vast applied literature. One branch of this, the work with cost functions, was deemed appropriate for industries in which output decisions were exogenous. For example, utilities in which companies were charged with meeting all consumer demand for a good or service at a given price. Water utilities fell squarely under this heading. But it was the US electricity industry that proved the most fertile testbed for empirical researchers.[62] The water industry was largely neglected. One reason for this lay in the lack of reliable water industry data, which limited both the quantity and quality of the empirical work. Nevertheless, a sufficient number of studies have emerged to comprise a literature which reflects many of the post war theoretical developments.

Early Work.

The earliest published econometric work for the UK water industry was that by Ford and Warford (1969). They employed cross sectional data on water supply companies in England and Wales for the year 1965-66 to estimate a series of basic cost functions. The aim was simply to model production, not to come to conclusions over efficiency measurement. The functional forms taken included the quadratic, logarithmic, semi-logarithmic and the exponential. Output was defined in quantity terms and assumed homogeneous, although some adjustment for non-

[62] See for example Cowing and Smith (1978) and Christensen and Greene (1976).

homogenous production conditions was made by including 'area' and 'population' as variables in the linear regression. Results were generally very poor and few diagnostic tests considered beyond simple R^2 and t statistics. The authors suggested two reasons for the poor results. First, misspecification of the dependent variable. Second, and more interestingly, that certain 'unquantifiable' variables not included in the specification had swamped the effects of the independent variables used. They were unable to include other so-called 'technological' variables for lack of data; but drew the policy conclusion that savings in costs were possible through the rationalisation, ie merging, of operations. They confirmed the tentative nature of the results by arguing that they should be seen as a qualitative not quantitative guide to policy.

In the light of recent advances in econometric theory and technique it would be easy to highlight flaws in the paper: the primitive functional form employed, the elementary criteria for assessing the estimated model, the poor data, the complete omission of prices in the cost function. But going beyond these criticisms credit should be given for the attempt to break new ground and for the insight that the poor results may - at least in part - be attributed to the omission of unquantifiable variables. In other words, in this study there is the early indication that a hedonic approach of one form or another may be appropriate to the modelling of the industry.

The industry received very little attention in the following decade until Knapp (1978) presented results of cost function work for the English and Welsh sewerage industry. Using 1972/3 data he found strong and pervasive economies of scale in the purification and disposal of domestic and industrial sewage. But the paper had an importance beyond giving weight to the idea that the industry enjoyed economies of scale.

In many ways, sewage treatment and disposal was the 'Cinderella' function of the water supply industry. Despite being amongst the oldest and most essential of services, researchers chose to neglect it in favour of its superficially more alluring sister, water supply. Knapp's contribution was and remains the only UK empirical study published in a mainstream economics journal. Furthermore it was innovative by taking into account the quality as well as quantity dimensions of output. Knapp himself noted that there were no previous UK studies that addressed the question of economies of scale within a framework that took account of the volume of sewage treated and the extent of the treatment. From a technical point of view the work is open to many of the criticisms levelled at Ford and Warford (1969): the omission of input prices due to a lack of data, the parsimonious functional form dictated by 'empirical considerations', the use of operating cost as the dependent variable ignoring the role of capital in this capital intensive industry. But the work is redeemed by its innovative use of measures such as sewage strength and purification method, which proxy the quality of output. In addition he defended the behavioural assumption of cost minimisation whilst admitting that the function estimated was only that of a short run cost-output relationship. Thus although the omission of price variables amounted to misspecification his findings of an 'L' shaped average cost curve, giving the industry natural monopoly characteristics, appear sound.

Property Rights Issues.

The next notable contribution to the literature came in the same year but concerned the water supply function. In this

Crain and Zardkoohi (1978) set out to employ a cost function to assess the relative performance of public and private water companies in the US. Taking a property rights approach to the question, using cross sectional data for 1970 on 24 private and 88 public water utilities, they rejected the hypothesis that operating costs for public and private utilities were equal. Private companies were found to be more efficient. The functional form employed was Cobb Douglas, with a physical output measure, prices for labour and capital and dummies for public and private companies. Although no adjustment was made for 'hedonic' variables (those that captured the quality of output) the paper represented an advance on Ford and Warford (1969) and Knapp (1978). It employed a theoretically sound cost function with well-investigated and recognised properties and input prices were included as arguments in the specification.

Efficiency was assessed by examining the elasticities of output with respect to labour and capital. They found that the marginal product of labour was higher in privately owned firms than in their public counterparts. But the absence of variables modelling differences in operating conditions did raise the question of whether the results were reliable. If further conclusions were to be drawn as to comparisons of efficiency between different companies the question would be serious. Given the more limited problem of comparing public and private companies as a whole the use of dummies would appear adequate for the task.

Bruggink (1982) tackled the same issue but came to a quite different conclusion. Setting out to examine the effects of ownership on technical efficiency he specified a linear cost function which allowed for variation in environmental, regulatory and wage variables. An ownership dummy was designed to pick up residual effects that could be attributed to different patterns of property rights. Using 1960 US cross sectional data the finding was that public ownership led to lower operating costs. The existence of economies of scale was also confirmed. The methodology was, however, flawed by the use of operating cost as the dependent variable. For this capital intensive industry, capital costs were excluded from the regression. Taken with the findings of Crain and Zardkoohi (1978) the picture of the industry was becoming less and less clear. A new approach to the analysis was needed.

By the early 1980's many researchers had taken on board the flexible functional form literature and were applying it in the various empirical studies. In addition hedonic analysis enjoyed something of a revival. In a seminal contribution to the literature Spady and Friedlaender (1978) successfully integrated the hedonic and flexible functional form literature in their examination of the US trucking industry. They found that to omit variables capturing quality variation lead to misleading results when modelling producer behaviour. Feigenbaum and Teeples (1983) recognised the importance of the work and applied the insights to their analysis of the US water industry.

Following Crain and Zardkoohi (1978) and Bruggink (1982) they addressed the property rights question of the impact of ownership form on costs of operation. Their innovation was to include variables as proxies for service dimensions, but to reject the multiproduct approach used before in favour of a hedonic cost approach. They argued that because of the continuous nature of water supply service dimensions a hedonic method would be preferable to a multiproduct approach that would treat different levels of service attributes as distinct goods. For water, a multiproduct approach would imply the specification of a very large (in theory an infinite) number of outputs. This would severely restrict the number of degrees of freedom available for statistical estimation. They concurred with the view of Neuberg (1977), that since the service attributes were interdependent and could not be priced and sold separately it would be inappropriate to employ a joint cost model to characterise utility activities.

The paper tackled several drawbacks which appeared in the previous studies. These included: the improper measurement of firm output as a scalar value representing delivery volume, arbitrarily imposed specifications of production technology and the omission of relevant factor prices. A multidimensional index of firm output was constructed, its arguments being service attributes associated with delivery. The specification assumed that 'bundles' of water volume, quality and service attributes could be consistently aggregated by a function Q(.) to ensure comparability between firm outputs, and, following Spady and Friedlaender (1978), they specified a quality separable hedonic cost function. This implied that a firm's service mix was independent of relative factor prices.

The functional form employed was:

$$C = C(Q(Y; z_1, z_2 \dots z_m); r_1, r_2 \dots r_n) \qquad [3.19]$$

where C represented costs, Q the aggregated (hedonic) output index, Y the output volume, r_i the input prices and z_i the service attributes. The function Q(.) was assumed to be homogeneous of degree one with respect to volume Y. This implied:

$$Q = Y.g(z_1, z_2 \dots z_m) \qquad [3.20]$$

where g(.) was the hedonic function aggregating the service dimensions of the firm. A translog cost function was the specific functional form employed where:

$$\ln Q = \ln Y + \ln g(z_1,\ z_2 \ldots . z_m) \qquad [3.21]$$

The hedonic term lng(.) was approximated by:

$$\ln g(.) = \Sigma\ a_i\ \ln z_i \qquad [3.22]$$

and interaction effects in the cost function were omitted to avoid the problem of multicollinearity.

A nonlinear maximum likelihood technique was employed in estimating the function with three input prices and six service attributes (z_i). US cross sectional data for 1970 on 57 private and 262 public water companies formed the sample. Overall, in contrast to the previous studies they found no significant difference in relative efficiency between firms under different ownership. The pooling of the two types of firm could not be rejected. However hedonic and non-hedonic results were different. Non-hedonic estimates suggested that water delivery technology was not homogeneous, consequently a Cobb Douglas specification was only deemed appropriate when output was defined in hedonic terms. The point was significant since the non-hedonic Cobb-Douglas model was the one most frequently used in previous studies; and was the only specification that allowed the rejection of the pooling hypothesis for private and government water utilities. They stated,

> "Our results indicate that a Cobb-Douglas production function is an appropriate specification only if the multidimensional nature of water delivery is incorporated into the model"[63]

[63] Feigenbaum and Teeples (1983) p677.

This study broke much new ground and set the course for later work. Its primary importance came through the application of hedonic pricing theory to the specification of industry cost functions. But the work was not left uncriticised. McGuire and Ohsfeldt (1986) argued that the work was lacking in terms of its data and methodology; biasing the results in favour of the conclusion of no cost differences. They held that Feigenbaum and Teeples' use of accounting data did not reflect the true opportunity cost of resources. In addition they argued that differences in accounting practice made the data incomparable. The second main point was that the wrong null hypothesis had been used. Instead of taking equal efficiency as the null, McGurie and Ohsfeldt suggested testing whether private enterprises were less costly than public firms. Other points of contention included the assumption of cost minimisation and estimation without cost share equations leading to inefficiently estimated cost parameters.

In a reply Teeples, Feigenbaum and Glyer (1986) argued that their study followed in the tradition of other work. The use of accounting information and the behavioural assumptions had all been adopted before and were a common starting point for the work. They pointed out ways in which they modified the accounting data to try and capture 'economic costs': by controlling for water inputs, by constructing a capital price index, by using regional prices for labour and energy weighted by occupational mix and size of firm. But having done all that imperfections persisted, and these imperfections were very difficult to remove. It does indeed appear that McGuire and Ohsfeldt were being unduly harsh in singling out this one particular study for criticism. And whilst their criticisms had some substance as they related to public and private sector efficiency comparisons they had less to say about the hedonic specification itself.

As if to compound the rebuttal and confirm the original approach taken, Teeples and Glyer (1987) presented a revised set of results confirming their original conclusions on the insignificance of efficiency differences between public and private water utilities. Taking a general second order translog cost function they compared the three cost models of water delivery systems, replicating the results of Crain and Zardkoohi and Feigenbaum and Teeples. These emerged as special cases of the general functional form. Cross sectional data for 1980 on 119 Southern Californian water delivery systems was employed, and yielded enough information to permit the estimation of cost share equations. The usual behavioural assumptions were made and a hedonic function constructed with 'z' variables and ownership dummies once again. The results indicated that as the model specification became more complete the efficiency differences between public and private operations were reduced to insignificant levels. This may explain why apparently contradictory results were previously obtained. The function met all the regularity conditions including linear homogeneity in input prices, concavity and downward sloping factor demands.

But whilst this reestimation addressed the methodological criticisms of McGuire and Ohsfeldt quite clearly, the question of data deficiencies remained. For although certain adjustments were made in the accounting numbers, it remains the case that they are a poor proxy for economic measures of opportunity cost. They are, however, the best available at present. It remains the responsibility of the researcher to recognise these deficiencies.

Other Approaches.

For completeness, three other pieces of empirical work must be included in this brief review. The first by Clark and

Stevie (1981) incorporated spatial features in the mathematical modelling of a total cost function for water. The cost function was assumed to be separable; comprised of the costs of water treatment, and the cost of transmission or distribution. Using US data a function was constructed which assumed circularity and radial symmetry of demand, with the population density falling exponentially with distance from the treatment source. In contrast to the other papers reviewed, the relationship was deterministic rather than statistical with the results reliant on the particular, rather restricted set of assumptions made for the service area and pattern of demand. Although adjustments may be made for non-circular service areas and different population distributions the algebraic operations involved quickly became intricate. Results of the work suggested that there was a trade off between economies of scale for the production and treatment of water, and diseconomies of scale in transporting it to its point of use.

Fox and Hofler (1986) offered a different approach to the measurement of water utility efficiency by estimating homothetic composed error frontiers. This is one of the earliest pieces of work on the industry to apply the insights of Aigner, Lovell and Schmidt on frontier estimation. Before this paper, published work had not considered the explicit testing of efficiency, but had looked at the question of whether cost structures differed between firms in the public and private sectors. By using frontiers, Fox and Hofler were able to judge the actual cost or production performance against the corresponding potential for individual firms.

They employed a dual production function to account separately for the production and distribution roles of water utilities. Essentially, this was a multiproduct analysis with the different operations being specified as different outputs. A system of equations was estimated with US cross sectional data for 1981 on 156 public and 20 private utilities. It was found that overall the pooling hypothesis could not be rejected, in line with the results of Teeples and Glyer (1987). But on this point they offered more discrimination. For whilst overall efficiency was generally similar, private companies proved to be more allocatively efficient than their public counterparts. Relative technical efficiency was more evenly balanced. So although the study was innovative in its use of frontier function estimation and confirmed many earlier findings it was flawed in two ways. First in its use of a production function to model an industry in which output was largely exogenous. Second in its use of a multiproduct rather than a hedonic function.

Another multiproduct analysis of water was given by Kim and Clark (1988), who specified residential and non-residential services as their two outputs. A translog multiproduct cost function was estimated jointly with cost share equations. This included operating variables (such as capital utilisation and service distance) and input prices with a carefully defined price of capital (interest rate on long term debt plus an allowance for depreciation). Again American cross sectional data was used for 60 water utilities in 1973. And whilst no economies of scale were found in the overall operation, there were significant economies for non-residential water supply and diseconomies for residential water supply. Predictably they found economies of scope associated with the joint production of the two services.

The paper, although not presenting the results of frontier estimation or hedonic work did offer some new insights. An innovative approach was taken to defining outputs, a well specified cost function was employed with a price of capital as one of the arguments

Recent Work.

It is appropriate to end the review by returning to the initial point of departure: the English and Welsh water industry. Two papers, one by Lynk (1993) and the other by Price (1993), have broken the silence of nearly two decades on econometric studies of the domestic industry. And for that, credit must be given.

Lynk's (1993) study attempted to measure the efficiency of the statutory water companies and the Regional Water Authorities (RWA's) in the pre-privatisation industry. Multiproduct, frontier cost functions were specified and estimated using data for the RWA's for 1979/80 to 1987/8, and for the statutory companies for 1984/5 to 1987/8. He argued that the cost function needed to be sufficiently general to admit all influences upon costs, including the impact of joint production, yet avoid over-sophistication in the use of interaction terms, since these might induce harmful multicollinearity. For this reason a simple log linear cost function was specified. In other words, the functional form owes little to the flexible functional form literature discussed earlier.

For the RWA's a multiproduct rather than hedonic approach was adopted; the drawbacks of which have already been discussed. Three outputs were used, corresponding to water, sewerage and environmental services. Operating cost was the dependent variable with only one input price (labour) entering as an argument. Firm and time dummies allowed the estimation of a 'fixed effects' model with the panel data. One innovation was the use of quality adjusted output measures. Results suggested that the RWA's enjoyed economies of scope; ie the benefits of joint production of water supply and sewerage, and water supply and environmental services. Reductions in service quality were found to reduce the degree of benefit of joint production, whilst there were noticeable regional and time effects.

For the statutory companies a single output cost function was estimated in the similar way with panel data, regional and time dummies. Once again regional and time dummies were significant.

The study's most interesting results however are those reported following frontier function estimation by corrected ordinary least squares. The results were interpreted for models of the RWA's with and without quality adjustment, and for the statutory water companies. They suggested that relative to its own efficiency frontier the publicly owned companies operated at significantly lower levels of inefficiency than privately owned companies.

Given the strong assumptions made for the purposes of modelling the conclusions are presented boldly by Lynk. Although he breaks new ground in reporting frontier function estimation results there are several deficiencies. The lack of any rigorous appeal to economic theory for the cost function's specification is clearly a drawback. The omission of all prices except that for labour must cause some concern in any empirical study of such a capital intensive industry. Little is made of the data as a panel and the number of observations is fairly small. Finally, the companies are studied over different time periods. So all these factors must temper the enthusiasm with which the results are received.

The work of Price (1993) concludes this chapter. The paper containing the results was the first research paper published under the auspices of the Office of Water Services (Ofwat). It summarised work by the regulatory body on the issue of comparative efficiency measurement in the English and Welsh water industry from 1989 to 1993. Technically the paper was primitive, reminiscent of the work of Ford and Warford (1969). Operating cost is the dependent variable for linear equations estimated by ordinary least squares. No prices were included in the equation, but instead there was an attempt to employ hedonic variables such as pumping head and average size of borehole in the regression. These were used to correct for differences in company costs that may not be attributable to variations in other operating conditions. For comparisons of company efficiency no frontier results were offered. Instead companies were ranked according to their position with respect to the fitted line. Residuals were used to capture the differences between actual and predicted performance.

Given the primitive econometric techniques employed, Price pointed out that the modelling could, at best, merely suggest the position of companies with respect to their efficiency. But more may be said in the paper's favour. It may be argued that the data used in the estimations is the most reliable ever to emerge from the industry. Thanks to the efforts of Ofwat, backed up by legislation, companies' reporting conventions have been harmonised to an unprecedented degree since 1989. Many resources have been invested in the process and this has brought in data of the very highest quality. There remains great potential to use the data in new ways by employing more sophisticated analytical techniques.

Conclusion.

With the theory in place and with past empirical work as a guide, the way now lies open to undertake comparative efficiency measurement work. This is the work of the following two chapters.

Chapter 4.

Comparative Efficiency Measurement: Water Supply in England and Wales.

Introduction.

We now turn from the theory of modelling producer behaviour to the practical implementation of a system of comparative efficiency measurement for the water supply industry in England and Wales. For this purpose the tools of regression analysis proposed by Shleifer (1985), discussed in the literature review, will be used. However, they are employed as a means to an end. The end being the drawing of comparisons pertinent to implementing a system of yardstick competition. Significantly this implies that ordinal rather than cardinal measures are required. The work is 'ring-fenced' by the need to derive an efficiency ranking for the firms, rather than absolute measures of firm efficiency. In this, the work differs from many of the previous studies, except perhaps Price (1993), and does not set out to answer questions concerning the relative efficiency of public and private companies, and other related property rights issues. This chapter develops a series of comparative efficiency measures that are robust enough in their ordinal rankings of companies, and that may be adopted by the water industry's regulator.

The chapter is structured in the following way. It begins with a discussion of the physical processes involved in the supply of water. Institutional development and database construction are then outlined followed by an introduction to the modelling techniques used, and the results of the econometric analysis. The chapter ends with conclusions.

Physical Attributes and Processes.

At a global level, the earth's water resources are governed by the hydrological cycle. A system in which precipitation leads to further cloud formation by processes of evaporation and transpiration. But although vast quantities of water move through the system every year only a small percentage of that water is available for human use. It is this scarcity that underpins the economics of water supply.

Essentially, water resources and their use are separated in time and space. Consumers require a reliable and continuous supply, but rainfall is unpredictable and intermittent. Therefore water companies set up to meet the space-time mismatch by collecting, storing, treating and distributing water.

In England and Wales approximately half of all rainfall is lost to the atmosphere by evaporation or transpiration from vegetation. The balance, residual rainfall, goes to replenish rivers, lochs, reservoirs and groundwater storage regions.[64] The latter comprise water bearing strata which receive the water that has percolated through from the surface. Recent estimates of resources available for abstraction suggest that overall only 15% of residual rainfall is used for abstraction. This implies that England and Wales as a whole enjoy abundant water resources. Regionally, however, there is considerable variation. Residual rainfall is highest in the North West and Welsh areas, and lowest in East Anglia. Abstraction as a proportion of residual rainfall is highest in the South East of England and lowest in the South West and Wales.

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[64] This discussion is based on information presented by UBS Phillips and Drew (1989), Table 5, Rainfall and Abstraction 1987/8.

This pattern of abstraction has emerged because, spatially, the areas of highest rainfall are not necessarily the areas of highest demand. Consumer and industrial demand are concentrated around the main conurbations which are not all located in the wettest regions. So the companies must seek to meet the demand given the resources available. And these are determined, to a large extent, by the geological characteristics of the region.

For the purposes of classification a useful distinction may be drawn between underground or 'groundwater' sources (recovered from aquifers via wells, boreholes and adit systems) and 'surfacewater' sources (drawn off from reservoirs,lakes, canals and rivers). Nationwide, a similar proportion of water is abstracted from upland reservoirs (surfacewater), rivers (surfacewater) and groundwater. But, once again, there is considerable regional variation reflecting the geological characteristics of the different areas. Most groundwater abstraction occurs in the central, south and east areas, through which run the two major aquifers: the Upper Cretaceous aquifer running through East Anglia and points South West and the Permo-Triassic Sandstone aquifer running up from central England towards the North West. Hence companies in the South East of England draw much groundwater from the Chalk Downs; those in the North West rely upon the reservoirs of the Lake District and Penines for their surfacewater.

But this is not to say that groundwater and surfacewater sources are unconnected. They are interdependent parts of the complex hydrological cycle. Reservoirs may be used to regulate river flow, and rivers loose water which will percolate down through layers of rock to groundwater reservoirs. Both sources are replenished by rainfall, with the aquifers not only acting as direct sources of water, but also providing a natural baseflow for many major river systems.

Abstraction is the first task of the water company; whether from groundwater or surfacewater sources. The second task is treatment. Consumers demand water of a certain minimum quality; consequently firms must invest to bring abstracted water up to this standard. Treatment methods are again determined by the raw material. So, as a general rule, groundwater requires less treatment than surfacewater before being put into the public supply. The process of percolation is in itself a process of filtration by which many of the impurities are removed. However, typical processes for surfacewater treatment include: storage, screening, aeration, clarification (coagulation and flocculation), sedimentation, filtration, the use of granular activated carbon, pH adjustment and disinfection.[65] Groundwater may only require disinfection with a compound of chlorine but it is common for the processes of softening and aeration to be applied.

Once treated, the water must be delivered to consumers. Two issues arise here. First, continuity of supply. Some means of storage is required to guard against temporary interruptions in supply or brief spells of dry weather. For companies extracting groundwater the problem is less pressing. The aquifer acts as a storage reservoir of high quality water. Consequently the rate of supply is determined by the rate at which water may be pumped to the surface and treated. But, for those treating surfacewater it means heavy capital investment in storage capacity at surface level. Nevertheless the advantages do not run in just one direction. If groundwater is drawn off at a rate greater than the natural rate of replenishment then there may be a lowering of the water table. This may impose

[65] See 'Water Treatment' (1990), and information leaflet published by the Water Services Association, London.

negative externalities on those depending on good river flows. On the other hand, expensive storage lagoons for surfacewater allow sunlight to penetrate the water and kill off many harmful bacteria.

The second issue is distribution; the spatial problem of how to deliver water resources to their point of use. In Roman Britain, the problem was solved through the use of aqueducts for bulk, and pipes for small scale transmission. In modern times aqueducts linking Manchester to supplies from the Lake District were commissioned in 1894. Birmingham's solution was to draw water from the Elan reservoirs in Wales. Other more sophisticated water management solutions have included the regulation of river flow to bring water from reservoirs over long distances to the point of abstraction. Then, once abstracted and treated, the water is fed to individual consumers through large distribution mains from service reservoirs branching into smaller mains which eventually reach individual houses. The distribution systems are designed to accommodate diurnal and seasonal variation in demand, so typically operate below capacity. Mains water is delivered under pressure to ensure an adequate supply to buildings of normal height and also to avoid the possibility of contamination through infiltration by foreign bodies.

All this means that a substantial capital investment is made in the distribution system. Given that the water is supplied under pressure, leakage often occurs but unless catastrophic, this is difficult to detect. Indeed, in practice the effort and cost of locating and repairing the fault frequently outweigh the water saving. This is particularly true for mains laid at some depth along main roads.

To summarise, the costs of the physical processes of abstraction, treatment and distribution are frequently determined by the geological profile of a region. Groundwater, being of high quality, requires little treatment; and natural storage in the aquifer reduces the need for the capital intensive facilities required of surfacewater outlets. Fluctuations in consumer demand may be met by additional pumping time. Surfacewater often requires elaborate treatment plant and large storage facilities, although variable costs of surfacewater abstraction may be less than groundwater, with stations being supplied under gravity. Setting to one side for the moment a discussion of the idiosyncratic nature of many of the plants and sources, and a discussion of the capital investment issue, a broad ranking of the costs of abstraction and treatment may assist an intuitive appreciation of the problem. Thus as a first approximation; groundwater abstraction with no treatment works ranks as the lowest total cost operation, followed by surfacewater abstraction with treatment works but no reservoir and surfacewater abstraction with treatment works and reservoir.

Institutional Development.

Various institutions have delivered these different water services to the population of mainland Britain over the last century. Historically, the industry in England and Wales was dominated by three categories of organisation; water undertakings, sewerage and sewage disposal authorities and river authorities. Legislative innovations reinforced a process of concentration, consolidation and movement towards a system of integrated river basin management that culminated in the current integrated institutional structure. Each branch of the industry enjoyed several unique characteristics in terms of its organisational evolution, however for the purposes of the current analysis attention will be confined to water undertakings.

At the turn of the century there were approximately 2000 separate water undertakings in England and Wales variously, abstracting, distributing and treating water. Some were private companies or local authority waterworks operating under private Acts of Parliament. Others were local authority waterworks operating under 19th century public health acts or joint water boards formed by the combination of two or more local water undertakings. By 1950 the number of individual suppliers had fallen to 950, the figure was 276 in 1968, and of the 187 suppliers on the eve of the 1974 reorganisation 100 were water boards, 57 local authority undertakings and 30 private companies. The main legislative initiatives over the period were the 1936 Public Health Act which laid down duties regarding the sufficiency and quality of water, and the 1945 Water Act which recodified and consolidated all the relevant provisions of former legislation into one structured 'Waterworks Code' covering the duty to supply, the compulsory purchase of land etc. Significantly, the Act also encouraged the amalgamation of water suppliers to form water boards aimed at increasing efficiency and exploiting economies of scale. As indicated by these statistics, the process gathered momentum in the two decades following the Act.

The most significant institutional development in the industry came about with the 1973 Water Act which established ten Regional Water Authorities (RWA's) in England and Wales[66]. In order to achieve economies of scale and scope and a higher level of pollution control the three

[66] The Water Authorities came into existence on 1st April 1974.

main branches of the industry were amalgamated on a regional basis under the general principle of 'Integrated River Basin Management'. The new authorities inherited a bundle of operational, environmental and regulatory functions including responsibility for water supply, sewerage, sewage disposal, water resource planning, pollution control, fisheries, flood protection, water recreation and environmental conservation. Their role was to plan and control all uses of water in each river catchment area. Whilst the organisational developments brought about by the 1973 Act have a parallel in the nationalisation of the electricity and gas industries, nationalisation was not complete with the new authorities retaining a majority of local government representatives on their boards, and only a minority of central government appointees including the chairman. This arrangement was modified and nationalisation completed[67] by the 1983 Water Act which stipulated a maximum board size of fifteen, consisting of members appointed by central government ministers. The new authorities were chiefly responsible to the Department of the Environment (Welsh Office for Welsh Water) except on matters of land drainage and fisheries where they reported to the ministry of Agriculture, Fisheries and Food. Other bodies established under the Act were the National Water Council (an advisory body and industry association) and the Water Research Centre.

Of prime importance to the study is the fact that the private statutory companies survived reorganisation largely intact, under s12 Water Act 1973, even though the RWA's assumed responsibility for the supply of water in all areas. Where a statutory company operated within the area of the water authority, the authority was required to discharge its water supply and distribution functions

[67] Vickers and Yarrow (1988) p391 make the point concerning incomplete nationalisation.

through the company. Close cooperation was required as responsibility for water resource development lay with the authority, however in many operations the company acted as agents of the authority. Twenty nine of these statutory water supply companies operated between 1974 and 1989 under tight regulatory control. These controls concerned methods whereby capital could be raised, the rate of dividends, the amount of accumulated surplus carried forward etc. Supplying approximately one quarter of England and Wales's total water meant their combined contribution was significant throughout the period. Thus private and public suppliers of water co existed from 1974 to 1989.

The Water Act 1989 further altered the institutional framework transferring the functions of the water authorities relating to water supply and sewerage services to water service companies. A new body, the National Rivers Authority, responsible for river management was established and shares in the ten water service companies were offered for sale on 22nd November 1989. The statutory companies retained their areas of supply but several converted to PLC status as restrictions on the raising of capital were relaxed.

One of the most significant institutional changes brought about by the 1989 Act was the root and branch reform of regulatory arrangements covering the industry.[68] The water and sewerage companies, which took on the mantle of the Regional Water Authorities, lost their regulatory functions to new organisations set up under the Act, and thereby ceased to be both poacher and gamekeeper in terms of environmental regulation.

[68] The original legislation has been modified and consolidated by the Water Industry Act 1991, Water Resources Act 1991, Statutory Water Companies Act 1991, Land Drainage Act 1991, Water Consolidation (Consequential Provisions) Act 1991 and Competition and Service (Utilities) Act 1992.

At first sight the reforms appeared further to complicate the already complex regulatory arrangements. The following organisations all had a regulatory role under the new regime: the Department of the Environment and the Welsh Office, the Office of Water Services (Ofwat), the National Rivers Authority (NRA), the Drinking Water Inspectorate (DWI), the Office of Fair Trading (OFT), the Monopolies and Mergers Commission (MMC), HM Inspectorate of Pollution (HMIP), and the Ministry of Agriculture, Fisheries and Food. Unsurprisingly the relationships between the various agencies were complex and often the source of some conflict.[69] However, three core regulators now take a leading role in the day to day regulation of the industry. They are: Secretaries of State (drinking water quality) the National Rivers Authority (environmental regulation) and Ofwat (economic regulation).

The economic regulator, Ofwat, under its Director General, Ian Byatt, was assigned three main tasks; to ensure reasonable prices, satisfactory standards of service and adequate consumer representation. The levers of policy at Ofwat's disposal included the price cap (RPI+K), the service standards which it monitored and the Consumer Service Committees, appointed by the Director General to champion the interests of the consumers in their areas. Ofwat's use of comparators for economic regulation has been discussed in Chapter 2. However, it should be noted that the economic regulatory reforms of the 1989 Water Act provide part of the motivation for comparative efficiency measurement.

The new freedoms and opportunities opened up by the 1989 Water Act have meant that institutional development has continued. Companies have pursued their objectives in many

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[69] A discussion of the relationships between regulators is given in Byatt (1991).

different ways. To date, several water companies have diversified their operations and some of the original statutory companies have been taken over by larger British or French concerns. The process of consolidation continues. At 31st March 1993 only 32 of the original 39 companies were still in existence as individually licensed operators. This number will be reduced during the year as Severn Trent Ltd completes the takeover of East Worcester Water Plc.

Background to the Work.

We now turn from a description of the physical and institutional aspects of the water supply industry in England and Wales to the presentation of a method of comparative efficiency measurement. For the purposes of modelling, water companies are assumed to be price takers in factor markets minimising costs whilst delivering a level of output set exogenously. In line with the various econometric studies surveyed in Chapter 3, the proposed methodology involves the econometric estimation of a series of cost functions. Theoretically, their use is in harmony with the behavioural assumptions of cost minimisation and exogenous output. Practically, the unit cost function has a natural interpretation in terms of efficiency, with a crude first approximation of firm efficiency being given by the level of unit cost.

The econometric estimation of the theoretical model requires the adoption of a particular functional form that does not contravene the theoretical postulates. The transcendental logarithmic (translog) functional form of Christensen, Jorgenson and Lau (1973), outlined above, is selected as it imposes very few restrictions on the data and allows a very rich initial specification. The models with homogeneity, homotheticity and unitary elasticity of substitution may be nested in this general form and testing may proceed down towards a basic Cobb Douglas specification.

The key extension to the simple cost function is made through the adoption of various hedonic forms. Hedonic variables are included in the unit cost function in the way outlined in Chapter 3 in order to model the multidimensional nature of output in some way.[70] The continuous nature of the water service dimensions implies that an aggregation approach is preferable to a multiproduct approach which would treat different levels of service attributes as distinct goods. The choice of hedonic variables reveals implicit judgments as to which physical or operational aspects of company activities are significant in the cost minimisation decision.

The main technical extensions to the existing UK studies concerning the efficiency of the water industry, lie in the use of a new dataset and the application of the insights of research into stochastic frontier functions. And, in contrast to much previous work, the main aim is to derive an ordinal efficiency ranking; not to derive cardinal measures, or to draw conclusions regarding the relative efficiency of private and public companies.

A classical econometric testing strategy is followed, whereby a testable model is constructed on the basis of economic theory with a view to the available information, estimated and analysed. This general approach in the Hendry/LSE vein owes much to the work of Sargan (1964) but has applicability beyond the confines of time series analysis. The general principles of the approach are reflected in a methodology that involves the formulation of a general model consistent with the postulates of economic

[70] Following Feigenbaum and Teeples (1983).

theory. Reparametrisation follows in an attempt to obtain explanatory variables that are near orthogonal and 'interpretable' in terms of the final equation(s). Simplification and model parsimony are assumed desirable as an initial rich specification is tested down in a general to specific modelling strategy. However, lest the impression be given that the approach is totally prescriptive and mechanical, it should be mentioned that the modelling process often proceeds in a less rigid manner.

So, with the general modelling strategy outlined, attention may be turned to the data which will be employed in the estimation. The process of database construction and an evaluation of its properties is the subject of the next section.

Database Construction and Evaluation.

Prime facie, database construction would appear to be a straightforward exercise for an industry which, since 1974, has comprised integrated regional operators. In fact the position is quite different. Before the 1989 Water Act the picture was one of chaos and confusion. In their outstanding review of statistical sources for the UK water industry Penning-Rowsell and Parker (1983) made the point,

> "Taken as a whole, the data series on water services in the UK are both chaotic and generally very inaccessible. They pose innumerable problems for the researcher attempting more than a superficial analysis of spatial and temporal trends. In addition it should be stressed that the accuracy and appropriateness of much of the data may well be less than it appears, not least owing to irregular or inconsistent sampling, and that a most careful evaluation is necessary of any data used."[71]

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[71] Penning-Rowsell and Parker (1983) p191.

But what are the reasons for this 'chaotic' situation and the lack of any national database? Two points may be made here. The first concerns the regionalisation of the industry.

Whilst the reforms of the 1973 Water Act[72], led to a devolution of powers and responsibilities to Regional Water Authorities, attempts were made to maintain a national perspective through new institutions such as the Water Data Unit and the National Water Council (NWC). Both had national data gathering and dissemination roles. The Water Data Unit was closed in 1981, the NWC disbanded in 1983. Both closures deprived the industry of important national integrating organisations. Furthermore, in the run up to privatisation, RWA's faced an incentive structure which encouraged the cultivation of exclusive individual interests and the loosening of national ties. For, after 1989, partners in the industry were to become competitors.

The second reason for the 'chaotic' national picture was the process of institutional reform itself, mentioned above. The life cycle of the Water Data Unit illustrates the point well.

As part of the 1973 reforms the Water Data Unit came into being in 1974 under the control of the Department of the Environment.[73] Its main functions were to advise on the standardisation of water data collection, to collect and process water data required for project planning and to

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[72] Under the Act, ten Regional Water Authorities were established. The principle of 'Integrated River Basin Management' was enshrined in the final settlement.

[73] Under s1 of the Water Act 1973 the Secretary of State for the Environment was given the statutory duty to collate and publish information relating to water resources and their use.

provide a computer processing service for the water industry. The unit sponsored research into data gathering and published several series of water statistics. In 1981 the unit was dismantled and a variety of agencies took over its responsibilities; including the Department of the Environment, the Ministry of Agriculture, Fisheries and Food and the National Environment Research Council. Whilst the Department of the Environment was the nominal clearing house for data, no other national database was established for that period. Only in 1989 did Ofwat begin work on devising such a database for its own comparative efficiency studies.

The lack of a coherent national database for the period 1974-89 severely inhibited empirical research in the UK. The situation may be contrasted with that in the US, in which comprehensive statistics published by the American Water Works Association enabled the studies outlined in Chapter 3 to be carried out. Consequently, in undertaking original research for England and Wales it was necessary to construct an entirely new database suited to the work in hand. Given the complexity of the industry's institutional structure and the intricate division of functional responsibilities, this proved to be a non-trivial, labour-intensive task.

I took a systematic approach to the work. Rather than setting out to gather all available data that came to hand, I began by organising two field trips. These enabled me to gather information on the physical processes and the institutional framework of the water supply industry quickly and efficiently. This knowledge was used throughout the study to inform decisions made in database construction. An appreciation of the activities of abstraction, purification and distribution also meant that I was aware of the extent to which assumptions made, for the convenience of modelling, departed from reality.

The first field trip was to Yorkshire Water's Tophill Low Water Treatment Works near Driffield in East Yorkshire. The trip took place on Friday 13th December 1990 and I was guided by the Chief Engineer, Mr D Roberts. The second was to the Water Services Association, 1 Queen Annes Gate, London, for an interview with Mr Peter Hall (Assistant Secretary Finance and General Policy) on 18th March 1991. The Water Services Association as an industry body representing the water companies gathers and publishes data for the industry as a whole. Consequently it was an appropriate opportunity to acquire background information on the institutional structure and development of the industry.

The next stage was to trace the published material in University, National and Corporate libraries. As this proceeded a 'data inventory' was drawn up, listing the individual data sources, their contents and location. (A abridged list of these is given in Appendix 2.) Primary sources included: the annual reports and accounts of the RWA's and statutory water companies, the Digest of Environmental Pollution and Water Statistics (Department of the Environment), and publications of the Water Authorities (Services) Association. Secondary sources included: the Annual Report and Accounts of the National Water Council (dissolved in 1983), publications of the Water Companies Association and various reports of the Monopolies and Mergers Commission. Individual figures were then transcribed to standard tables and committed to computer spreadsheet, checked at every stage and backed up by full handwritten documentation.

In data gathering the aim of the study - ie the estimation of a hedonic cost function - determined the data to be acquired. But the rule was not followed rigidly. Where information was available but did not appear to have immediate relevance its location was noted. Often these sources would be returned to, once other avenues had been explored and proved fruitless. Revision and updating were essential parts of the whole process as more reliable or more comprehensive sources of data were discovered. Throughout, the importance of consistency, continuity and reliability in the data series were borne in mind. This often resulted in a long but inconsistent time series being replaced by one that was apparently more reliable but shorter. Where series differed the reasons were investigated and the more reliable adopted.

Table 4.1, below, lists the variables comprising the final dataset used for empirical testing.

Table 4.1: Database Variables.

AREA	Area of supply (square kilometres).
POPU	Population (thousands).
MAIN	Length of mains (kilometres).
EMPL	Total number of employees.
RAIN	Rainfall (mm per year).
WATE	Output (megalitres per day).
SRWT	Surfacewater (proportion of total water abstracted from surfacewater sources - percentage).
GDWT	Groundwater (proportion of total water abstracted from groundwater sources - percentage).
OPCT	Operating cost (thousands of pounds).
CAPE	Historic cost capital expenditure (thousands of pounds).
TSCT	Total staff cost (thousands of pounds).
FIXA	Fixed assets historic cost net book value (thousands of pounds).
CCFA	Fixed assets current replacement cost (thousands of pounds).
PK	Price of capital (public works loan board average rate of interest on new advances).
PE	Price of electricity (average net selling value per kilowatt hour sold for waterworks etc , pence).
PR	Price of rates (average non domestic rate poundage for English authorities, pence).
PL	Price of labour (average hourly earnings for manual men in other energy and water supply industries, pence).
PP	Price of other materials (retail prices index).

Although the simple variable definitions appear fairly unambiguous, in many cases they conceal several rather sweeping assumptions. Therefore the use of this data in empirical analysis must be informed by knowledge of the heterogeneous collection methods, definitions and reporting conventions employed by the different water suppliers. Consequently the main features of each will be outlined to ensure their interpretation and use is better informed.

Area (AREA) represents the area of water supply operations. For the statutory companies this will be straightforward. For the RWA's this is often considerably less than their total administrative area because of the presence of the smaller companies acting as agents in their region. Population (POPU) is taken to be the population of the water supply area. In general over 95% of the resident population is connected to the public water supply. This rises to over 99% in many regions. Where there is the choice of winter or summer resident populations, the figure for winter is chosen. The higher summer populations reflect only the temporary influx of holidaymakers. Resident population rather than 'equivalent population' is used. for whilst 'equivalent population' is available for the Water Authorities, the statutory water companies seldom report this figure.

The length of mains (MAIN) is estimated in kilometres. Companies vary considerably in the reliability of their estimates and the completeness of their records. RWA's, for example, inherited assets from many small operators; some of whose records were incomplete or lacked precision in terms of the location of the mains network. Often the figures offered are highly subjective, based on an engineer's best estimate. As replacement and renewal occurs, records are updated. Consequently the reliability of this measure continues to improve over time.

The total number of employees (EMPL) was taken to be the average number of full time equivalent staff. However, for water authorities this statistic was not generally broken down by function, therefore this represents employment for the whole of the operation. Rainfall (RAIN) is reported for each area. Where statutory companies did not report the figure it was proxied by using the value for the corresponding Water Authority area. The locations of statutory companies within Water Authority areas are set out in Appendix 3.

Output (WATE) is measured in megalitres per day.[74] It usually represents the total amount of water put into the supply per day. This differs from the quantity of water consumed or demanded for consumption by the amount of water lost in the distribution system as a result of leakage.[75] It should be noted that for this variable there are some differences in the way in which water authorities and statutory water companies collect the figures. However the series obtained showed a good degree of continuity within companies over time.

The proportions of total water resources abstracted from groundwater and surfacewater sources were recorded as percentages (GDWT, SRWT). These were variously defined in the source documents as volume of water abstracted or volume of water put into supply. For individual companies the figure showed little variation over time. Where gaps existed in the dataset for individual years they were plugged using an extrapolated figure.

Operating cost (OPCT) was a key variable derived from the accounts with great care. For the RWA's the figure was taken from the subjective analysis of turnover and operating costs which they reported on a functional basis. This was convenient and meant that figures for the RWA's excluded any element of cost of water resources or sewerage work. The data was therefore broadly comparable across the public / private company divide. Further work was conducted on the raw data to ensure that an operating cost was taken which excluded any element of capital cost. This was a

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[74] One megalitre is equivalent to a million litres or a thousand cubic litres.

[75] Estimated leakage is reported in 'Business Monitor - Quarterly Statistics' of the Business Statistics Office, HMSO (PQ603). Estimated wastage from public mains as a percentage of water supplied to own customers for 1980,1981 and 1982 was 20%, 21% and 22% respectively.

difficult process but necessary to preserve the integrity of the data. So, from the cost figure were excluded: depreciation, interest payments, taxes, contributions to the National Equalisation Fund, contributions to the National Water Council and the Water Resource Centre. Items included were, operating, maintenance and administration costs; together with other charges of a similar nature. Some discrepancies were unavoidable. For example, the figures for York Waterworks include some elements of chargeable services that are difficult to disentangle. Some discrepancies were undetectable: considerable variation was permitted under accounting conventions in the assigning of items of expenditure to revenue or capital accounts. Nevertheless the final figures may be taken to be a reasonable proxy for operating cost over the period.

Capital expenditure on the water supply function was recorded as CAPE. This was the figure for the additions to the stock of tangible fixed assets at their historic cost level. The RWA's conveniently recorded water supply figures separately from other functions. Again figures were comparable between statutory companies and RWA's. Total staff cost (TSCT) represented wages and salaries for both manual and non-manual workers.

In this capital intensive industry, two measures of capital stock were recorded. The first was the historic cost net book value of fixed assets (FIXA). Once again the figure for all RWA's was broken down by function. For statutory companies the figure was purged of any element referring to the issue of redeemable preference shares and loan capital in the early years. The second measure of capital stock was CCFA, a measure of the current gross replacement cost of tangible fixed assets. No depreciation was deducted and figures were available for the water supply function only. However information on this variable was only reported by

RWA's and statutory companies from 1980/1 onwards. Furthermore, although water authorities continued to report the variable throughout the period of study many of the statutory companies discontinued the reporting of this series in the middle of the decade. To overcome the problem missing values of the data were calculated using the Public Works Non Roads Index Annual Multiplier. This was applied to the figure for Historic Cost Capital Expenditure leading to figures going back to 1977/8 for all companies, and going forward to 1986 for the statutory companies.

Five price terms were employed. The price of capital (PK) was the Public Works Loan Board average rate of interest on new advances. This was considered appropriate as, throughout the period, RWA's had obtained all their long term sterling borrowings from the National Loans Fund. Governments pursued this borrowing policy for all statutory corporations in order to preserve flexibility in its own borrowing operations. The prices of power (PE) and rates (PR) were straightforward. The first was the average net selling value per kilowatt hour sold for waterworks etc, and the second was the average non-domestic rate poundage for English Authorities.

The price of labour (PL) was the price term with the greatest amount of cross sectional variation. Figures were taken from the New Earnings Survey (NES) on the average hourly earnings for manual men in other energy and water supply industries. The data for manual workers are used as it may be argued that, at the margin, it is the wage rate for manual workers that determines decisions regarding the appropriate labour / capital mix. Appendix 4 lists the classification of the various companies into NES regions. Finally, PP represented the price of all other materials. A finer subdivision of input prices was not feasible given the data available from primary sources. Therefore the

Retail Prices Index was considered an appropriate fifth price.

Of the variables in the database the price of capital and the measurement of capital stock are most important and most difficult to deal with. Table 4.2 gives some indication of just how capital intensive the industry is. Consequently, in such a capital intensive industry variation in the procedures adopted for capital valuation will have a profound effect on any results derived. The whole question has been tackled recently by Farber (1989) in the context of utility regulation. Farber (1989) conducted tests of whether various measures of the price of capital and capital stock influenced measures of electric utility allocative efficiency. By employing a theoretically 'correct' Jorgenson-type price for capital services he showed that the method for measuring capital stock did not have as large an effect on the efficiency conclusions as the method of price measurement. The point is made that the treatment of capital is one of the linchpins of any modelling exercise.

The point is noted, but data availability conditions the response that can be made to the issue. However, in an attempt to address the problem the two methods of capital stock valuation used in the database contribute to two of the three unit cost definitions used in the econometric work.

Unit cost is defined in three ways: as operating cost per unit of output (OPC/Y), as historic valuation operating cost per unit of output (CHC/Y) and as current valuation operating cost per unit of output (C/Y). The numerator of each of these unit cost terms - OPC, CHC and C - will now be discussed in more detail. The denominator (Y) representing output is the same in each case.

The first measure (OPC) reflects a 'pure' operating cost excluding, as far as possible, any cost of capital or charge for the capital stock employed. Hence the variable is purged of any measure of depreciation before it is employed.[76]

The second measure (CHC) adds into the operating cost a proxy for the working cost of capital. This proxy is a charge based on the historic net book value of physical assets. The capital charge is obtained by multiplying the net book value of fixed assets at their historic cost (FIXA), by the price of capital (PK - the Public Works Loan Board average rate of interest on new advances). Using the above notation the capital charge is simply (FIXA x PK). This figure is then added to the operating cost OPC, to give CHC.

The third measure (C) is compiled in a similar way. This time a current cost capital charge is added to the operating cost. The capital charge is obtained by multiplying the price of capital (PK) by the current gross replacement cost of tangible fixed assets, with no depreciation deducted (CCFA). The figure for the current gross replacement cost of tangible fixed assets is derived from reported current cost accounting statements, and where data is missing an imputed value is used as discussed above. Hence the current cost capital charge may be written (CCFA x PK); and is added once again to the operating cost OPC, to give C.

However, it should be made clear that all these attempts to account for the price of capital and the value of the total stock have imperfections. The measurement of capital stock - under both accounting conventions - and the use of only

[76] OPC is merely another name for the variable labelled OPCT above. Its derivation was discussed earlier.

one price are approximations. In terms of capital stock valuation it is clear that much capital stock goes unrecorded by the companies (eg mains) or has been fully depreciated over its life (eg Victorian pumping stations). If this is the case no record of the stock will appear on a company's historic cost balance sheet; consequently any measure of capital stock derived from this source of information will be flawed.

The current cost measure of stock is an improvement; offering an approximate, but satisfactory, current value for the replacement cost of assets[77]. However, even this approach can do nothing to mitigate the problem of unrecorded assets. No national database exists with information concerning the differing vintages of capital equipment, and the useful lives of many of these assets are uncertain. Whether current cost valuation gives a more accurate representation of the stock of capital compared with historic cost procedures is a moot point. It is hard to dispel the lingering impression that capital stock valuation in this industry has a certain arbitrariness. Renewals accounting is the latest methodological innovation under consideration to deal with the problem, in which the infrastructure assets are considered to have infinite lives with the operating capability being maintained, by incurring renewals expenditure, at a constant level in real terms. Clearly the results of the analysis will be affected directly by the accommodation made for capital measurement.

By employing only one price of capital the database is deprived of another source of cross sectional variation. Again the approximation is flawed to the extent that

[77] The Office of Water Services (Ofwat) currently (1993) use this current cost information in regulating the domestic water industry.

different companies and authorities were able to obtain funds at different rates of interest. The proxy (Public Works Loan Board average rate of interest on new advances) is, however, appropriate given the fact that over the period of the study the Government's general policy was that borrowing in sterling by statutory corporations other than for temporary purposes would be obtained from the National Loans Fund. Information concerning the rates at which individual water suppliers borrowed during this period was not in the public domain, and could not be obtained for the purposes of this research.

Given all these reservations it may still be argued that the treatment of capital, and the inclusion of proxies for capital cost in the various models is an appropriate way to proceed. Specifically, care is taken in the study to abstract from the capital problem in the first instance, and then to deal with it in line with two currently accepted accounting procedures. Alternative approaches were available and could have been used in this context. For example the capital charge could have been proxied either by the depreciation charge for capital stock in the year, or by a figure representing additions to stock (tangible fixed assets). Both are unsatisfactory compared with the approach explained above and adopted.

The depreciation figure is flawed as water companies and authorities had not harmonised accounting policies at the time of the study. Consequently there were substantial differences in depreciation adjustments employed by the various organisations. Furthermore, many large assets with long useful lives did not appear on historic cost balance sheets, having been fully depreciated. Thus any historic cost depreciation figure would be very misleading. Use of a figure representing additions to tangible fixed assets may also be criticised as being a poor proxy for capital cost. Although it may be argued that, over the period of the study, capital expenditure was chiefly replacement investment this is clearly a strong assumption. In addition by using this figure, only one capital charge is obtained. Under the alternative approach adopted, both a historic and a current charge are employed. This enables a preliminary assessment of the sensitivity of the results to the particular capital accounting treatment to be made.

Despite these obvious difficulties over accounting for capital and the compromises made in constructing the database much may be said in its favour. Primarily it is the first of its kind: new work which, however imperfectly, sets about controlling for the cost of capital in this capital intensive industry. It should also be noted that financial data on the industry contained in publications such as company reports are consistent and reliable. In contrast to the physical measures reported, the financial statistics have undergone an audit process in every case. And despite the format of both statutory water company and Water Authority accounts being changed by the Companies Act 1985 and the Water Act 1983 respectively [78] these publications remain easily accessible and reliable sources of information.

In addition comparable figures for the multifunctional water authorities and unifunctional statutory water company operations were available. Water authorities invariably met their obligation over the period to report key variables on a function by function basis. Hence data on water supply operations is distinguished in the annual reports from data on water resources, sewage treatment and disposal

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[78] Under the provisions of the Water Act 1983 the format of Water Authority accounts changed between 1982/3 and 1983/4. Pre 1985 the format of accounts for Statutory Companies was governed by the Companies Act 1948 s149A schedule 8a.

operations.

Given this wide trawl for data what factors finally determined the shape and size of the database used in econometric work?

For the purpose of modelling it may be argued that a period of institutional stability alleviates many problems inherent in time series or cross sectional analysis. For with data on only thirty-nine individual water suppliers, some time series element would be necessary to provide sufficient degrees of freedom. Against this the ongoing process of institutional reform meant that data at this level of aggregation was only available for just over a decade for each supplier. Consequently cross sectional work would enter the analysis. From the point of view of time and industry configuration the period 1974-89 stood out clearly as a period of unmatched institutional stability in the English and Welsh water industry. Interestingly it was a time during which public and private companies undertook many similar functions in different geographical areas. Also, current cost data became widely available for the first time at the turn of the decade.

But even over this period records were incomplete or unavailable. Data series were often reported fitfully by companies responding to new external pressures and incentives. The consideration of data availability eventually lead to the selection of a working database comprised of observations from twenty companies over the ten year period 1977-86. In other words, a panel of two hundred observations. Appendix 1 lists the companies comprising the sample.

The choice of time period should not be seen in a purely negative light. The period 1977-86 was one in which the reforms and institutional flux induced by the 1973 Water Act had largely worked through the industry. Equally, preparations for privatisation leading to the setting up of water service companies in 1989 were only in their infancy[79]. The choice of water supply companies was equally appropriate. The sample comprised the ten Regional Water Authorities and ten statutory private water companies. These exhibited good geographical, geological and meterological variation.

Summarising, the database used in the empirical analysis was comprised of a sample of twenty water suppliers for the period 1977-86. Table 4.2 reports basic descriptive statistics for each variable.

[79] It is notable that information reported by water suppliers declined in scope and detail following the 1983 Water Act and in the run up to privatisation. See for example the Annual Report and Accounts of Northumbrian Water. Statutory water company data contained in its 1983/4 report no longer forms part of the 1988/9 report.

Table 4.2: Descriptive Statistics.

VARIABLE	MINIMUM	MAXIMUM	MEAN	STD DEV
AREA	104	22710	6700	7383
POPU	131	7315	2114	2305
MAIN	853	38350	12122	12112
EMPL	100	12061	3065	3509
RAIN	572	1483	888	229
WATE	40	2720	692	775
GDWT	0	100	40	33
SRWT	0	100	60	33
OPCT	927	140121	28795	32013
CAPE	-127	66142	12009	14321
TSCT	348	135419	27032	33356
FIXA	3160	464668	91836	101189
CCFA	23147	2857600	622545	679689
PK	9.13	14.63	11.54	1.61
PE	1.95	3.89	3.17	0.74
PR	79.4	212.6	143.5	44.9
PL	163.0	506.7	335.7	113.4
PP	47.5	99.3	76.2	17.5

Before leaving this discussion the question of hedonic variables should be addressed. Once again scope for discussion is limited by the availability of data; but guidance may be sought for their specification in the work of Feigenbaum and Teeples (1983) and their innovative modelling of the water industry.

In their study of the US water industry Feigenbaum and Teeples (1983) selected six service characteristics as hedonic variables. Some of their data was derived from subjective estimates by employees in the industry.[80] UK data is again found wanting in comparison, being uneven and even more limited in scope and depth. However, five service dimensions are derived from the variables above and employed in later testing. They are labelled as follows:

z1 = % surfacewater abstracted,
z2 = resident population/area of supply,
z3 = resident population/length of mains,
z4 = length of mains/area of supply,
z5 = length of mains/resident population.

z1 may be regarded as a proxy for water treatment, surfacewater being more expensive to treat, hence more capital intensive in recovery, but cheaper in terms of variable costs of supply. The other variables are different attempts to proxy population density. Note that z3 and z5 are merely the inverse of one another.[81]

This concludes the discussion of the database. But before any modelling is attempted one other issue should be addressed. The issue arises as a consequence of the limited size of the database and is the question of panel data.

<u>Panel Data.</u>

A database comprising annual observations on a total population of 39 companies for the period 1974-89 clearly presents sample size problems for time series or cross sectional econometric work. When this is further

[80] For example Feigenbaum and Teeples (1983) use z1 to represent a treatment index derived from subjective cost weights supplied by a district water engineer and a water facility design engineer.

[81] Note that many may be collinear, therefore careful functional form specification and interpretation will be required.

restricted to 20 companies over a 10 year period as in the present case, statistical analysis is severely impaired through the limited degrees of freedom available. The conventional way to proceed is through the use of a panel data set recording multiple observations on individual units over time. The principal advantages of this approach derive from the enlarged set of data points available to the researcher, increasing degrees of freedom, reducing collinearity among explanatory variables and hence improving the efficiency of econometric estimates. In addition, a wider group of more complex problems may be analysed.[82]

The present comparative efficiency study seeks to model heterogeneity across the sample of companies, in such a way that idiosyncratic attributes outwith the control of individual companies are accounted for. Informally, the aim is to construct a 'level playing field', enabling fair comparison. The more completely the exogenous idiosyncrasies are controlled for, the better the comparison. Panel data is employed in the estimation of specific functions to complete this task. The two most widely used approaches to modelling with panel data will be discussed briefly: the 'fixed effects' and the 'random effects' models. A fuller presentation may be found in several standard econometric texts. [83]

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[82] A comprehensive discussion of the panel data issue is given in a monograph by Hsiao (1986).

[83] For example Judge et al (1982) and Greene (1990).

For the purpose of illustration consider a model of the form

$$y_{it} = \alpha_i + \underline{\beta}'\underline{x}_{it} + v_{it} \qquad [4.1]$$

with N firms i=1...N and T time periods t=1...T. There are k regressors in $\underline{x}_{it}$ not including the constant term; y_{it} is the dependent variable and α_i represents the effect peculiar to the individual cross sectional unit i but constant over time. The error v_{it} is a classical disturbance term with $E[v_{it}] = 0$ and $var[v_{it}] = \sigma_v^2$. In effect this is a classical regression model, in which ordinary least squares (OLS) estimates of α and β will be consistent and efficient.

The fixed effects or least squares dummy variable model (LSDV) works on the assumption that the different cross sectional units provide natural partitions in the sample for which different functional representations may exist. The model is a special case of the Zellner 'seemingly unrelated regression model' and assumes identical coefficients on all variables except the intercepts. This is in effect a classical regression model with differences across units captured in the constant term. The natural development is to specify dummy variables corresponding to each firm in the following way,

$$\underline{y} = \underline{D\alpha} + \underline{X\beta} + \underline{v} \qquad [4.2]$$

Estimation may proceed by OLS giving results which are best linear and unbiased . Theoretically the estimation procedure is straightforward and its interpretation clear with the classical properties and results carrying over directly. Some numerical problems may be encountered if the number of parameters is large, although these may be overcome by straightforward partitioning. Ordinary least squares has the advantage of simplicity, and when applied to the unit cost function in the context of a fixed effects model has a straightforward economic interpretation. As the unit cost schedule shifts so the intercept changes ie differences in unit costs and hence efficiency between firms may be characterised as parametric shifts of the regression function. Initial testing must establish whether there is evidence to suggest that the different companies had different intercepts or whether the model would be adequate with all intercepts identical. In the latter case a straightforward pooling of data to give NT observations would be appropriate. An F test is used in this case. Estimation proceeds with n dummies and no constant or n-1 dummies and a constant.

The random effects or error components model employs the notion that individual specific constant terms are more appropriately viewed as randomly distributed across cross sectional units. This is relevant if it is believed that the sampled cross sectional units are drawn from a large population. The random effects model is a generalised regression model with generalised least squares yielding best linear unbiased estimates. The general model specified above may be reformulated,

$$y_{it} = \alpha + \underline{\beta x}_{it} + u_i + v_{it} \qquad [4.3]$$

with k regressors in addition to the constant term. u_i is the random disturbance component characterising the ith observation and is constant over time. Generalised least squares may be conducted in two stages, firstly estimating the variance components by using the OLS residuals, and then computing feasible GLS estimates using the estimated variances.

In empirical studies a choice may be made as to which model to pursue. In this the relative sizes of the cross section (N) and time series (T) may be considered; for as T tends to infinity for fixed N, the dummy variable estimator and the error components estimator become identical. When N is large and T small the two estimators can differ significantly with the fixed effects estimator being consistent but not asymptotically efficient. No absolute choice rules may be applied here but several criteria suggest the appropriate model. Judge et al (1982) frame the discussion in terms of conditional and unconditional inference. They argue that if individuals can be regarded as a random sample from some larger population that we are concerned to make inference about then the unconditional inference implicit in the random effects model is appropriate. Conversely, if the sample may not be considered as randomly drawn from some larger population then conditional inference carried in the fixed effects model appears appropriate. Mundlak (1978) goes further to suggest that this distinction between fixed and random effects is an incorrect and arbitrary one and the conditional inferential approach should always be employed.[84]

For the present study, the conditional or fixed effects approach would appear appropriate, for it would be hard to maintain that the sample was a random drawing from a large population. This is an institutional point. The fixed effects model also leads naturally to the derivation of efficiency rankings. Meanwhile the random effects model labours under the assumption that the individual effects are uncorrelated with the other regressors. Inconsistency due to omitted variables may result. Thus, once again, the fixed effects model is favoured.

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[84] See Hsiao (1986) for a fuller discussion.

Hausman (1978) presented a statistical test which contributes to the analysis. The chi-squared statistic can be employed to test whether the GLS estimator of the random effects model is an appropriate alternative to the least squares dummy variable estimator of the fixed effects model. The test is essentially one of othogonality between the random effects and the regressors. Under the hypothesis of no correlation both OLS in the fixed effects model and GLS are consistent but OLS is inefficient. Under the alternative OLS is consistent but GLS is not. Hence under the null the two estimates should not differ systematically and a test can be devised based on the difference. It should be noted that the test may be inconclusive; in which case one may tentatively favour the fixed effects model in terms of ease of economic interpretation, and the avoidance of bias induced by omitted variables.

Given this information, the weight of evidence would appear to favour, a priori, the use of fixed effects models in the estimation of cost functions for this industry.

With a time series element present the possibility of autocorrelated error structures may arise. Structural equations for fixed effects model may be written as follows,

$$y_{it} = \alpha_i + \underline{\beta' x}_{it} + v_{it} \qquad [4.4]$$

$$v_{it} = \rho \, v_{i,t-1} + \eta_{it} \qquad [4.5]$$

Adjustment for first order autocorrelation may be made with the estimation proceeding in two stages. Firstly the model is estimated ignoring possible autocorrolation, this gives a consistent estimate of the parameter ρ. This is then employed in the second GLS step. This Cochrane Orcutt transformation of data implies

$$z_{it} = z_{it} + \rho\ z_{i,t-1} \qquad [4.6]$$

consequently the first observation in each group is lost. For the fixed effects model the transformation is

$$y_{it} - \rho y_{i,t-1} = \beta'(x_{it} - \rho x_{i,t-1}) + \alpha_i(1-\rho) + \eta_{it} \qquad [4.7]$$

Frontier Estimation with Panel Data.

The use of panel data also has implications for the techniques and assumptions underlying the econometric estimation of frontier functions. Whilst several improvements can be made to the estimation methods for stochastic frontiers outlined in Chapter 3 (and employed later in Chapter 5) there remain some shortcomings.

The improvements, when panel data is employed, include the ability to drop the assumption of normality and the avoidance of the problem of non-convergence when calculating inefficiency for individual observations using the techniques of Jondrow et al (1982). The chief drawback is that with fixed effects models the analyst must revert back to what is essentially a deterministic rather than a stochastic frontier model. Consider once again a simple stochastic cost frontier model similar to that discussed in Chapter 3. The only difference now lies in the addition of both firm (i) and time (t) subscripts. As before, v represents the two sided random error and u the term capturing the effects of inefficiency.

$$\ln C_{it} = \alpha + \ln C(y_{it}, w_{it}) + u_{it} + v_{it} \qquad [4.8]$$

If u_{it} and v_{it} are independent over time as well as across individuals then the panel nature of the data set is in effect irrelevant. Frontier estimation may proceed as before. But new possibilities open up when the panel dataset is acknowledged and turned to good advantage. These new insights may be gained if one is willing to make a further assumption about the nature of inefficiency. So, assuming u_{it} is constant over time[85], the model may be rewritten,

$$\ln C_{it} = \alpha + \ln C(y_{it}, w_{it}) + u_i + v_{it} \qquad [4.9]$$

Under this assumption the u_i terms may be treated as firm-specific constants and the model estimated by ordinary least squares as a 'fixed effects' model.[86] To extract estimates of the individual effects the set of firm-specific constants (α_i) are derived using the least squares dummy variable estimator. These are then used in the following way to extract the estimated firm-specific effect ($\hat{u}_i$).

$$\hat{u}_i = \hat{\alpha}_i - \min_i \ (\hat{\alpha}_i) \qquad [4.10]$$

This results in one firm reaching the frontier or benchmark value of zero and the remaining firms being ascribed positive inefficiency estimates.[87] For this model, no assumption of normality is needed and the estimates of u_i are consistent. Estimation is also consistent in T_i. Great care should be taken, however, over the specification of functions and the interpretation of results. Outliers may, as with all deterministic frontiers, exert a

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[85] This assumption is made by Schmidt and Sickles (1984) in their discussion of frontier functions and panel data. It will be followed throughout the rest of the chapter.

[86] The point is discussed by Greene (1993).

[87] Greene (1993) notes the proof of the proposition that shifting the estimated regression up or down so that exactly one residual is zero produces a consistent estimate of the constant.

disproportionate influence on the final results. In addition, the ever-present danger is that variation in firm attributes is picked up in the term designed to capture inefficiency. The implication is that hedonic models are more reliable in taking this effect into account.

Schmidt and Sickles (1984) published early work on this question. They noted that the consistency of the estimates improved asymptotically with N and T and that this consistency did not hinge on the uncorrelatedness of the regressors and the individual effects. Adapting the argument of Greene (1980) for the single cross sectional case, they said that provided the density of u_i is nonzero in some neighbourhood $(0, \epsilon)$ for some $\epsilon>0$, the efficiency of the most efficient firm in the sample will indeed approach 100% as $N\to\infty$. Asymptotically it was possible to separate the overall intercept from the one-sided individual effects, which allowed the measurement of efficiency relative to an absolute standard.

When demonstrating the workings of the system they assumed Cobb Douglas technology but made the telling point that the small number of firms in their sample (N = 12) meant that the normalisation of the most efficient firm as 100% technically efficient was questionable. However, whilst they rejected these figures as absolute measures of inefficiency they had more faith in the relative efficiency rankings.

With a panel of only 20 companies over 10 years all the Schmidt and Sickles caveats apply. But whilst there is no consistent way of separating the overall intercept from the one sided effects it is possible to derive consistent estimates of the intercept for each firm. Thus, in line with their work it is possible to compare efficiencies across firms, ie derive an ordinal ranking, but not to

assess efficiency relative to an absolute standard[88].
Clearly the use of panel data raises many technical problems in the estimation. However, without these techniques results of time series and cross sectional models would be highly suspect given the rather limited dataset.

Modelling Results and Diagnostics.

Having discussed, briefly, many of the technical issues at stake in devising a system of comparative efficiency measurement - based on the econometric estimation of a series of cost functions - we are now in a position to report the results of the model building undertaken.

Models Employing the Translog Cost Function.

To recapitulate, the panel dataset used for modelling consisted of 200 observations on twenty English and Welsh water supply companies over the ten year period 1977/8-1986/7. Cost functions, taking the flexible translog functional form were employed within the two most common frameworks for pooling time series and cross sectional data - fixed and random effects.

A general to specific testing strategy was adopted beginning with the translog unit cost function subject to the standard regularity conditions. Models with restrictions implying homogeneity, homotheticity and unitary elasticity of substitution were nested in the general model and F tests used to asses the validity of

[88] Cornwell, Schmidt and Sickles (1990) relax the strong assumption of time invariant inefficiency by including time terms in the regression. This technique is too demanding in terms of degrees of freedom to be employed with the panel of 200 observations. The superiority of this technique remains unproven.

restrictions in testing down towards more parsimonious functional forms. Unit cost was defined in the three ways discussed above, namely: operating cost purged of the cost of capital divided by output (OPC/Y), operating cost with a historic cost of capital element divided by output (CHC/Y) and operating cost with a current cost of capital again divided by output (C/Y). Hence the three dependent variables, average cost per unit output normalised on the price of labour. Successive specifications used four, three and two input prices together with the various hedonic variables, singly and in combination.[89] Diagnostic testing completed the work.

The potential problem of endogeneity exists in all work of this sort, causing bias and inconsistency in OLS estimates. For the supply of water in England and Wales the problem is present but it may be argued that the problem is probably not chronic. Companies are price takers in the labour and capital markets and must endeavour to supply all water demanded at a price. Furthermore, in a ten year panel the marginal additions to capital stock made by companies will be overshadowed by the vast stock of inherited fixed assets. In other words the assumption is that the stock of capital is exogenous.

Six preferred models corresponding to the hedonic and non-hedonic versions of equations with the three dependent variables are reported in Table 4.3 below. These were arrived at through the process of general to specific testing which began with the most general translog models. Estimation results from the most general models were, without exception, very poor. The models exhibited symptoms of degeneracy with almost identical dummy variable coefficient estimates and corresponding standard errors.

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[89] Avoiding possible collinear combinations.

Coefficients were frequently incorrectly signed and parameter estimates were unstable. The results were unsurprising, given the amount of cross sectional variation in the data and the fact that translog functions were very demanding in terms of degrees of freedom.

Having rejected these as unsatisfactory the process of testing down began. This had its own difficulties. Tests were generally ill defined, inconclusive or contradictory in some cases. The process was compromised to such an extent that, in order to cut the Gordian knot, a strategy was adopted that proceeded on the basis of deriving a well defined model with parameter estimates broadly consistent with economic theory.

The results for six preferred models are given in Table 4.3 below. A non hedonic and hedonic version of models with each of the three dependent variables. Models numbered with the suffix 'h' represent hedonic specifications. Variables D1 - D20 represent firm dummies and ρ represents the autocorrelation coefficient. Appendix 1 identifies the firms corresponding to each of the dummies.

Table 4.3 One Way Fixed Effects Models Adjusted for First Order Autocorrelation.

Models 1.1 and 1.1h Dependent Variable = Ln(OPC/Y)-LnPl
Models 1.2 and 1.2h Dependent Variable = Ln(CHC/Y)-LnPl
Models 1.3 and 1.3h Dependent Variable = Ln(C/Y) -LnPl

EXPLANATORY VARIABLE	MODEL 1.1	1.1h	1.2	1.2h	1.3	1.3h
lnY	0.1792‡	0.0623	-0.2739‡	0.0029	-0.1735‡	0.0793
	(0.0423)	(0.0427)	(0.0501)	(0.0538)	(0.0619)	(0.0644)
ln(Pe/Pl)	0.7628‡	0.9167‡				
	(0.0573)	(0.0500)				
ln(Pk/Pl)			0.5500‡	0.6102‡	0.5768‡	0.6284‡
			(0.0196)	(0.0197)	(0.0238)	(0.0235)
lnZ1		-0.0307§		-0.0592‡		-0.0413§
		(0.0158)		(0.0186)		(0.0221)
lnZ2		-0.1066†				
		(0.0423)				
lnZ5				0.4442‡		0.5541‡
				(0.1156)		(0.1376)
D1	0.3581	2.1551‡	7.3231‡	4.0509‡	8.5509‡	5.3175‡
	(0.3147)	(0.4701)	(0.4675)	(0.6428)	(0.5524)	(0.7718)
D2	0.2871	2.1579‡	6.3220‡	3.4162‡	7.7629‡	4.8709‡
	(0.2909)	(0.4308)	(0.4272)	(0.5782)	(0.5041)	(0.6943)
D3	-0.2019	1.9294‡	7.2151‡	3.8824‡	8.5743‡	5.3646‡
	(0.3312)	(0.4809)	(0.5185)	(0.6464)	(0.6134)	(0.7766)
D4	0.1209	2.1407‡	7.2320‡	3.9773‡	8.6569‡	5.5218‡
	(0.3206)	(0.4728)	(0.4969)	(0.6276)	(0.5877)	(0.7540)
D5	0.3054	2.1772‡	6.8786‡	3.9649‡	7.9696‡	5.1434‡
	(0.2916)	(0.4263)	(0.4273)	(0.5606)	(0.5042)	(0.6734)
D6	0.4257	2.0924‡	6.9247‡	3.8669‡	8.5307‡	5.4383‡
	(0.2819)	(0.4360)	(0.4027)	(0.6067)	(0.4746)	(0.7282)
D7	0.0998	2.3212‡	6.4565‡	3.3928‡	7.8914‡	4.9925‡
	(0.3325)	(0.4746)	(0.5200)	(0.6031)	(0.6152)	(0.7248)
D8	0.5413§	2.3405‡	7.1633‡	3.9426‡	8.6045‡	5.4113‡
	(0.3013)	(0.4655)	(0.4542)	(0.6301)	(0.5365)	(0.7565)
D9	0.5316§	2.1341‡	6.8363‡	3.8442‡	8.3775‡	5.3989‡
	(0.2779)	(0.4257)	(0.3899)	(0.5770)	(0.4593)	(0.6928)

D10	0.3313	2.3049‡	7.3368‡	4.1503‡	8.5829‡	5.4913‡
	(0.3115)	(0.4613)	(0.4782)	(0.6181)	(0.5651)	(0.7424)
D11	0.7406‡	2.6199‡	6.1568‡	3.9498‡	7.6659‡	5.5539‡
	(0.2697)	(0.3669)	(0.3487)	(0.4356)	(0.4098)	(0.5232)
D12	1.1372‡	2.4664‡	6.0639‡	3.6227‡	7.7839‡	5.3451‡
	(0.2619)	(0.3582)	(0.2785)	(0.4662)	(0.3254)	(0.5596)
D13	0.7560‡	2.7085‡	6.6687‡	4.1875‡	8.3613‡	5.9706‡
	(0.2827)	(0.4015)	(0.4012)	(0.4989)	(0.4725)	(0.5992)
D14	1.1557‡	2.6712‡	6.6772‡	4.0682‡	8.1069‡	5.5135‡
	(0.2671)	(0.3852)	(0.3324)	(0.5045)	(0.3901)	(0.6057)
D15	0.6461†	2.5236‡	6.1532‡	3.6619‡	8.6533‡	6.2420‡
	(0.2781)	(0.3945)	(0.3896)	(0.4941)	(0.4587)	(0.5935)
D16	0.9873‡	2.8402‡	6.8113‡	4.5842‡	7.9944‡	5.8051‡
	(0.2663)	(0.3594)	(0.3322)	(0.4520)	(0.3898)	(0.5426)
D17	1.3142‡	2.8919‡	6.3625‡	4.2113‡	8.1966‡	6.2239‡
	(0.2645)	(0.3454)	(0.2819)	(0.3849)	(0.3293)	(0.4627)
D18	0.5212†	2.0402‡	5.1319‡	2.8104‡	7.1193‡	4.6696‡
	(0.2640)	(0.3712)	(0.3012)	(0.4936)	(0.3525)	(0.5921)
D19	1.4086‡	2.8040‡	5.7524‡	3.5966‡	8.7143‡	6.4444‡
	(0.2627)	(0.3527)	(0.2621)	(0.4628)	(0.3056)	(0.5549)
D20	0.7648‡	2.3062‡	6.1515‡	4.2868‡	7.5366‡	5.6399‡
	(0.2616)	(0.3391)	(0.2668)	(0.3994)	(0.3112)	(0.4791)
Adj R^2	0.716	0.794	0.897	0.918	0.872	0.892
F	22.525	31.084	74.894	87.997	58.939	65.011
ρ	0.021	0.006	-0.125	0.015	-0.035	-0.004
Returns to Scale	0.848	0.941	1.377	0.997	1.209	0.927

§ denotes statistical significance at the 90% level
† denotes statistical significance at the 95% level
‡ denotes statistical significance at the 99% level[90]

The preferred specifications are all one-way fixed effects models (ie those with firm dummies alone). Two way models with firm and time dummies were initially specified and likelihood ratio tests conducted to assess whether these

[90] Note that this labelling convention will be adopted in all following tables. Critical values for 90%, 95% and 99% significance are 1.645, 1.960 and 2.576 respectively.

were more or less appropriate than one-way specifications. However, these tests were inconclusive. Other factors influenced the selection of one-way models.

Firstly, it was recognised that two way models were very demanding in terms of degrees of freedom. This was an important consideration with a panel of only 200 observations. Data quality was recognised to be fairly uneven and the view was taken that there was a danger in using highly sophisticated technical tools on rather inadequate raw material. In this context the likelihood ratio tests give some guidance on the matter but they are persuasive rather than decisive. Consequently, the inclusion of both firm and time dummies was ruled out. This had the additional advantage of avoiding the potential problem of multicollinearity between time dummies and price terms. The point will be taken up later.

Secondly, in the context of yardstick competition, the primary analytical concern must be to model cross sectional variation rather than timewise evolution. In one sense the sacrifice is great, for it requires the strong assumption that influences that would have been captured in time dummies affect all firms in a similar way. Nevertheless, the key issue of comparative efficiency measurement for yardstick competition must drive the analysis, so it is most important to model cross sectional variation. Thirdly, it is arguable that one way models are more understandable to potential user groups, such as the regulator's office, than their two-way counterpart. Transparency is a subsidiary argument; but one that has a bearing on the adoption and implementation of any system by practitioners.

The arguments in favour of fixed rather than random effects models are more clear cut. From a theoretical point of view it is clear that a sample of 20 out of a total population of 39 cross sectional units (firms) cannot be regarded as a random sample from some larger population. This suggests that a fixed effects model, with its shift parameters, implying inference conditional on the cross sectional units in the sample, is more appropriate. Statistical confirmation of this was sought in the Hausman test for the orthogonality of random effects and the regressors. The statistic is distributed as χ^2, with rejection of the null hypothesis suggesting that the error components model is inappropriate. At the 95% level only models 1.2 and 1.3h fail (marginally) to reject the null. Consequently given the strong institutional argument for fixed effects and the need for comparability and transparency, fixed effects are reported in every case.[91]

All six models reported in Table 4.3 are reported following a Cochrane Orcutt adjustment for first order autocorrelation. In unadjusted models autocorrelation coefficients, ρ[92], strongly indicated the presence of positive autocorrelation which in turn implied inefficiency of parameter estimates invalidating R^2, t and F values.[93] The remedial action taken was conducted in two stages. First, estimation by OLS to give a consistent estimate of ρ; then generalised least squares (GLS) with a Cochrane Orcutt transformation of the model. This resulted in the

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[91] The fixed effects model also does not require the strong assumption of random effects models that individual effects are uncorrelated with the regressors.

[92] Values of ρ for the six unadjusted models were 0.462, 0.453, 0.484, 0.459, 0.457 and 0.462 respectively.

[93] See Greene (1990) Chapter 15 for a full treatment of the serial correlation, its diagnosis and suggested remedial action.

loss of one observation in each group.[94] Consequently, coefficient estimates reported refer to transformed data with the fixed effects dummy variable coefficients being $\alpha_i(1-\rho)$. Obviously the loss of the first observation in each set through the Cochrane Orcutt procedure is a drawback in a model using a dataset comprised of just 200 observations. Nevertheless t, F and R^2 statistics are more reliable and for this reason the transformed model is retained.

All six models display adjusted R^2 values upwards of 70%, whilst F values lead to the decisive rejection of the pooling hypothesis. More importantly the autocorrelation coefficient (ρ) approaches zero in each case suggesting the problem of first order autocorrelation has been dealt with adequately. All models are Cobb Douglas in specification: 1.1, 1.2, 1.3 representing nonhedonic forms and 1.1h, 1.2h, 1.3h the hedonic counterparts. The assumptions implicit in the Cobb Douglas specification may be reiterated to highlight their unrealistic nature. Thus results imply homogeneity of degree one in factor prices with constant elasticity of substitution between inputs and returns to scale which are the same for all levels of output. The last restriction rules out the possibility of increasing returns at low levels of output and decreasing returns at higher levels.

Throughout, the price of labour was chosen for all normalisations as, of all the price terms, it exhibited most cross sectional variation. With Pp (the retail price index) included in the specification, coefficients on other price variables became less well defined and behaved unpredictably. Multicollinearity is one possible reason for this. When prices of capital and electricity were specified in the same equation the effect was magnified. One

[94] See Greene (1990) p433.

explanation that may be offered in the context of a regulated industry is that companies have the ability to increase prices broadly at the rate of inflation, in contrast to costs which do not necessarily track the RPI. Only when the RPI was removed did the source of chronic multicollinearity disappear and the specification improve. The constant term was omitted from every equation to allow the inclusion of twenty firm dummies and to avoid perfect multicollinearity.

As discussed above, the three dependent variables dealt with capital cost in radically different ways. The capital intensity of the industry ensures that for models including any measure of the cost of capital, this element threatens to swamp total cost. The effect is less pronounced in the case of historic rather than current cost but the consequences are clear in terms of model performance. Thus models 1.1 and 1.1h have ln(Pe/Pl) as their significant price term. This is supplanted by ln(Pk/Pl) for the remaining models. All price terms were correctly signed[95] and significant at the 99% level, but in no case were more than two prices present in the preferred model.

The output term entered each preferred specification being positively signed in model 1.1 and negatively signed in 1.2 and 1.3. In all cases the coefficient was significant at the 99% level. It entered singly rather than in multiplicative combination with itself or other terms. On addition of hedonic variables to models 1.2 and 1.3 its sign changed, thus all hedonic models had the output term entering positively but insignificantly. It may be concluded that some of the 'output effect' was picked up by the term lnZ1 although potential multicollinearity did not appear so serious a problem to invalidate the results.

[95] An essential result for a theoretically consistent model.

The addition of hedonic variables did nothing to change the preferred specification; 1.1h, 1.2h and 1.3h remained two price Cobb Douglas models. lnZ1 took a negative sign suggesting surfacewater sourcing had some depressing effect on unit cost although this may in part reflect the realisation of economies of scale in the larger operations. lnZ2, an imperfect proxy for density, appeared only in the operating cost specification carrying a significant negative coefficient. This adds weight to the assertion that more densely populated areas have a lower unit cost of service. Addition of this variable controlled for differences in observable costs between water companies serving a broad rural/urban mix (usually the water authorities), and those located in areas of high population density (usually statutory companies).

The variable lnZ5 may be viewed as an imperfect proxy for capital assets, in its measurement of length of mains. A priori the expectation was that it would perform well in models 1.2 and 1.3. This proved to be the case, and it had no comparable discernable effect on model 1.1, which was set up explicitly to exclude capital cost. As a ratio it also proxied density and took a positive sign indicating that the higher the capital stock per head of population the higher was unit cost. The results are again consistent with a priori expectations which suggest that scattered rural communities may be more costly to supply because of their need for comparatively large investment in mains laying.

Returns to scale for each model were calculated. All models except 1.2 and 1.3 had near constant or decreasing returns to scale. In this it may be argued that economies of scale in the English and Welsh water supply industry have been largely exhausted at the current size and scale of activities. Although clearly increasing returns are expected up to a point in the storage, treatment and distribution of water.

Efficiency: The Translog Approach.

We may move on now to consider the end for which these models were built. The end of comparative efficiency measurement for yardstick competition. As was noted earlier, this requires an ordinal rather than a cardinal ranking of firms; from the most efficient to the least. Employing this information a regulator would be in a position to encourage all firms to perform as well as the leading one.

For this purpose a first approximation of firm efficiency may be derived from the intercept or firm dummy terms of the fixed effects model. Each dummy may be seen as capturing the idiosyncratic aspects of that firm's operations, including some efficiency element. The efficiency element is, however, inseparable from other influences picked up by the dummies. Hence the hedonic specification is employed to assist in the teasing out of some of these other effects. Intuitively, the greater the number of characteristics outwith the control of the firm[96] that may be removed from the dummy terms by their explicit specification in the estimating form, the more accurately the dummies reflect idiosyncratic efficiency decisions by the firm. The technique is necessarily crude, but not to be rejected simply on those grounds; and as a first approximation remains suggestive of efficiency rankings.

At this point the cost 'frontier' may be considered. As discussed earlier, the use of panel data with fixed effects models allows a frontier - deterministic in appearance - to

[96] ie Exogenous variables such as rainfall, population density etc.

be derived. Equation [4.9] illustrates the set-up. The firm dummies D1 - D20 correspond to variables u_i, the firm specific effects. By suitable manipulation, shown in equation [4.10], one firm may be deemed to lie on the frontier whilst the remaining firms take positive values of u_i lying above the efficient cost boundary. The absolute values of these adjusted residuals do give some indication of inefficiency in a cardinal sense; however, following Schmidt and Sickles (1984) more faith might be put in them as an ordinal ranking, given the limited number of observations.

Conveniently, no additional procedures, beyond simple arithmetic, need be gone through to derive frontier results. For panel data in fixed effects models OLS results carry over from the non-frontier to the frontier functions. Consequently residuals are identical and the comparative efficiency results will be the same for both. Inconveniently, the use of panel data in fixed effects models effectively means the abandonment of many of the well investigated properties of cross sectional stochastic frontier models. For the moment we work within these restrictions.

For completeness the adjusted frontier residuals are reported on Table 4.3F below.

Table 4.3F

	MODELS					
	1.1	1.1h	1.2	1.2h	1.3	1.3h
FIRM	$\hat{u}_i = \hat{\alpha}_i - \min_i (\hat{\alpha}_i)$					
1	0.5600	0.2257	2.1912	1.2405	1.4316	0.6479
2	0.4890	0.2285	1.1901	0.6058	0.6436	0.2013
3	0.0000	0.0000	2.0832	1.0720	1.4550	0.6950
4	0.3228	0.2113	2.1001	1.1669	1.5376	0.8522
5	0.5073	0.2478	1.7467	1.1545	0.8503	0.4738
6	0.6276	0.1630	1.7928	1.0565	1.4114	0.7687
7	0.3017	0.3918	1.3246	0.5824	0.7721	0.3229
8	0.7432	0.4111	2.0314	1.1322	1.4852	0.7417
9	0.7335	0.2047	1.7044	1.0338	1.2582	0.7293
10	0.5332	0.3755	2.2049	1.3399	1.4636	0.8217
11	0.9425	0.6905	1.0249	1.1394	0.5466	0.8843
12	1.3391	0.5370	0.9320	0.8123	0.6646	0.6755
13	0.9579	0.7791	1.5368	1.3771	1.2420	1.3010
14	1.3576	0.7418	1.5453	1.2578	0.9876	0.8439
15	0.8480	0.5942	1.0213	0.8515	1.5340	1.5724
16	1.1892	0.9108	1.6794	1.7738	0.8751	1.1355
17	1.5161	0.9625	1.2306	1.4009	1.0773	1.5543
18	0.7231	0.1108	0.0000	0.0000	0.0000	0.0000
19	1.6105	0.8746	0.6205	0.7862	1.5950	1.7748
20	0.9667	0.3768	1.0196	1.4764	0.4173	0.9703

For all twenty firms an adjusted residual derived from the estimated firm dummy (intercept) term is reported. For models 1.1 and 1.1h, firm 3 is the benchmark firm. For the other four models firm 18 is the benchmark. The higher the intercept value the higher the unit cost is assumed to be for each firm. The figures may be interpreted as measures of inefficiency relative to the 100% efficient firm. Thus for model 1.1 firm 1 is 56.00% less efficient than firm 3. Clearly the results are widely spread and rather implausible in many cases. This was predicted earlier. The problem may have been exaggerated as we are dealing with what is essentially a deterministic frontier model. Results of these are very susceptible to outliers and there is some evidence to suggest that firms 3 and 18 may be just that. Some sort of correction to omit these readings would undoubtedly improve the results. However the purpose of the study is not to assess by what amount any one firm's efficiency exceeds another's, but to rank the firms according to efficiency.

By ordering these intercept terms from the lowest to the highest, each firm is given a rank for each model. Table 4.3R below reports these rankings. Rankings are one to twenty within each model; one represents the lowest unit cost firm for the model and twenty the highest.

Table 4.3R

	MODELS					
	1.1	1.1h	1.2	1.2h	1.3	1.3h
FIRM	RANK					
1	7	6	19	14	14	5
2	4	7	7	3	4	2
3	1	1	17	9	15	7
4	3	5	18	13	19	13
5	5	8	14	12	7	4
6	8	3	15	8	13	10
7	2	11	9	2	6	3
8	11	12	16	10	17	9
9	10	4	13	7	12	8
10	6	9	20	16	16	11
11	13	15	6	11	3	14
12	17	13	3	5	5	6
13	14	17	10	17	11	17
14	18	16	11	15	9	12
15	12	14	5	6	18	19
16	16	19	12	20	8	16
17	19	20	8	18	10	18
18	9	2	1	1	1	1
19	20	18	2	4	20	20
20	15	10	4	19	2	15

Lowest cost rank = 1
Highest cost rank =20

Before proceeding the point must be made, once again, that these are not pure 'efficiency rankings'. These rankings represent the various idiosyncrasies of the firms, 'firm effects' picked up by the firm dummies in the econometric model. Clearly, the terms will pick up efficiency effects;

but in a limited way. With that caveat we may proceed to an interpretation of the results.

On first inspection the results appear almost random. On closer examination a pattern emerges. The ranking obtained from model 1.1 appears similar to that of 1.1h. Also 1.2 mirrors 1.3 and 1.2h reflects 1.3h. To formalise these results Spearman's coefficient of rank correlation (r) may be calculated for pairs of rankings.[97] r lies between +1 and -1. +1 indicating perfect positive correlation, -1 indicating perfect negative correlation and 0 indicating zero correlation. Spearman coefficients for various pairs of models are reported below.

Table 4.3S Spearman's Coefficient of Rank Correlation.

Models	r
1.1 and 1.1h	0.7744
1.2 and 1.2h	0.3925
1.3 and 1.3h	0.4120
1.1 and 1.2	-0.5398
1.1 and 1.3	-0.0782
1.1h and 1.2h	0.3835
1.1h and 1.3h	0.6857
1.2 and 1.3	0.5083
1.2h and 1.3h	0.5053

The first three values indicate, unsurprisingly, that there is a degree of positive correlation between the nonhedonic

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[97] Spearman, C. (1904) 'The Proof and Measurement of Association Between Two Things'. American Journal of Psychology, vol 15, pp 72-101. r is a non parametric statistic given by:

$$r=1-\frac{6\Sigma d^2}{n(n^2-1)}$$

where d = difference of rank and n = number of observations.

and hedonic versions employing the same definition of the cost of capital. Within the hedonic and nonhedonic testing frameworks models employing some cost of capital exhibit a positive degree of correlation ie 1.2 / 1.3 and 1.2h / 1.3h. A significant difference arises in correlation between 1.1 and 1.3 as compared with 1.1h and 1.3h. The first two have almost no correlation according to Spearman's r, yet 1.1h and 1.3h are very highly positively correlated. The conclusion may be drawn that the hedonic specification gives a greater degree of consistency in terms of ranking across definitions of cost and is therefore to be preferred.

The point may be made in another way. The maximum difference in ranking for any one firm between non-hedonic models 1.1 and 1.3 is 16 for firm 4. This may be compared with a maximum difference of 8 between hedonic models 1.1h and 1.3h. The total differences in positions between models 1.1 and 1.3 amount to 144, whilst those between 1.1h and 1.3h are 78. Again in terms of ranking differences or 'dispersion' hedonic models appear more concentrated than those of the nonhedonic counterparts. It may tentatively be concluded that rankings derived from the hedonic approach exhibit a greater consistency and therefore are of greater utility in assessing relative performance.

From a capital valuation point of view the historic cost specifications 1.2 and 1.2h are most open to the criticism of arbitrariness. Other models are perhaps better representations of the company's financial orientation, consequently less weight may be given to the rankings implied by the historic cost models. Nevertheless these results do not appear to be completely out of line with those having the current cost specification of the dependent variable.

Again the point must be made that these are rough approximations. Careful interpretation is everything. Over this time period firms displayed some variety in accounting treatments of various items. The rankings almost certainly include an 'accounting effect' and the individual circumstances and policies of the companies must inform the analysis. An example of this is firm 18 which appears to be an outlier in terms of modelling when a cost of capital is included in the specification of a dependent variable. Re-examining the raw data there is no obvious reason for this result. The accounting practices of firm 18 are clearly in line with other statutory companies. No error is apparent in scaling the data. One may with some justification draw the conclusion that firm 18's results reflect positively on firm efficiency. But the observation is clearly an outlier.

But despite this battery of caveats, the danger remains that a false impression of precision may be carried away by the user of this information. To counter this and to soften some of the finer distinctions a cruder 'banding' of firms is suggested. Consider the three hedonic specifications 1.1h, 1.2h and 1.3h. Firms which appear in positions 1-10 ie the lowest cost consistently may be assigned to Band 1 (low cost). Those appearing in positions 11-20 may be assigned to Band 3, and the remainder to Band 2. The picture is then as follows.

Table 4.3B. Efficiency Banding for Models 1.1h, 1.2h and 1.3h.

Band 1 Firms (low cost): 2, 3, 6, 9, 18.

Band 2 Firms (intermediate): 1, 4, 5, 7, 8, 10, 12, 15, 19, 20.

Band 3 Firms (high cost): 11, 13, 14, 16, 17.

Only one comment will be made concerning the banding results. It is that, apart from the outlier - firm 18 - all other firms identified as 'low cost' in band 1 are RWA's. Furthermore no RWA's appear in the highest cost band. Whilst all the usual caveats apply, and whilst it may be argued that the pattern picks up an institutional, accounting or ownership effect the finding remains. The result appears to support the work of Lynk (1993) in finding that the RWA's operated at lower levels of inefficiency than privately owned companies.

Overall then, this approach may serve to further attenuate the effects of differences between the accounting regimes at the cost of less precise rankings. Nevertheless the methodology is indicative of an approach that may be pursued in the practical implementation of yardstick competition. Specific relative efficiency conclusions would however require further investigation of the asset structure and accounting policies of the company.

A Rudimentary Modelling Approach.

The results for the theoretically consistent model are disappointing in the sense that the preferred Cobb Douglas functional form implies rather strong assumptions about producer behaviour. And although hedonic variables augment explanatory power the preferred specification is essentially unchanged. One conclusion that may be drawn is that the quality of the data is insufficient to support the heavy weight of econometric technique being laid on it.

In an attempt to address this problem the second part of the analysis presents an approach which may only be described as 'rudimentary'. In this the strict constraints of duality theory were set aside in the specification of a cost function. Three definitions of average cost (as outlined above) were used as dependent variables without being normalised on the price of labour: OPC/Y operating cost per unit of output per day, CHC/Y operating cost and historic cost of capital per unit of output per day and C/Y operating cost and current cost of capital per unit of output per day. The same panel data was employed in the specification and estimation of one way and two way fixed and random effects models. But this time explanatory variables were allowed to enter and leave the regression in additive and multiplicative combination according to whether or not they had a significant influence on the overall fit of the equation.

Table 4.4 records the new results.

Table 4.4 One Way Fixed Effects Adjusted for First Order Autocorrelation

Model 2.1 Dependent Variable = OPC/Y
Model 2.2 Dependent Variable = CHC/Y
Model 2.3 Dependent Variable = C/Y

Dummies $\alpha_i(1 - \rho)$

	MODEL		
EXPLANATORY VARIABLE	2.1	2.2	2.3
Y	-0.0149‡	-0.6176	6.3451‡
	(0.0049)	(0.4844)	(1.4750)
PL	0.0923‡		
	(0.0035)		
PK		82.5350‡	709.7900‡
		(11.8300)	(113.8000)
Z2	-3.0147		
	(2.9940)		
Z5			1101.0000‡
			(283.4000)
AREA		-0.1027†	
		(0.0478)	
MAIN	0.0003	0.1680‡	
	(0.0003)	(0.0461)	
EMPL	0.0031‡	-0.2846‡	-1.2255‡
	(0.0007)	(0.0401)	(0.3060)
GDWT	-0.0156	2.1019	6.9620
	(0.0471)	(2.0830)	(16.7000)
D1	1.7479	1243.6262†	-6727.1551
	(8.2170)	(498.1289)	(6109.5104)
D2	11.3544‡	288.9901	-15702.3064‡
	(3.1890)	(275.4611)	(4626.0960)
D3	4.4692	-273.6121	-14119.3163†
	(9.1563)	(543.6858)	(6628.4312)
D4	-2.9943	719.4525	-2899.3031
	(9.0609)	(523.8638)	(5989.2936)
D5	5.1285	1079.2327‡	-8937.9934§
	(5.5217)	(360.5331)	(4735.1737)
D6	5.1048	1086.2153‡	-8650.2420
	(4.1444)	(315.1225)	(5930.9550)
D7	13.7508	1546.9239‡	-14170.6996†
	(9.6918)	(562.8356)	(6172.5307)

D8	14.5179‡	2006.6696‡	-6069.4001
	(5.5668)	(554.5248)	(5605.7056)
D9	9.5779§	1345.3674‡	-7702.3601
	(5.5172)	(361.9332)	(5727.4778)
D10	12.0582§	664.9581	-6365.9725
	(6.6433)	(419.8726)	(5288.8674)
D11	24.6897‡	209.5763	-7531.1049§
	(7.9452)	(341.9184)	(3990.2378)
D12	24.1435‡	722.5932§	-9862.3642§
	(6.0231)	(381.9611)	(5415.0993)
D13	28.4428‡	616.1541†	-1723.6395
	(4.1453)	(264.3600)	(3601.6273)
D14	33.4168‡	1337.8026‡	-7385.4290
	(5.6294)	(368.6403)	(5249.4324)
D15	22.9921‡	-261.5486	3498.3503
	(4.6332)	(312.4533)	(3968.1636)
D16	31.0659‡	1820.0405‡	-3921.1299
	(6.3783)	(264.6193)	(3713.8821)
D17	42.6068‡	1456.0967‡	5015.9007
	(10.5767)	(391.0119)	(4343.3266)
D18	0.6839	-349.1828	-19462.8440‡
	(2.5514)	(242.6384)	(5050.3586)
D19	34.2291‡	645.8419‡	9281.6314§
	(2.7017)	(247.0430)	(5184.0984)
D20	6.5723†	1380.6856‡	-7721.8628†
	(3.0028)	(237.8233)	(3708.9609)
Adjusted R^2	0.883	0.749	0.659
F	54.785	22.325	15.412
ρ	0.008	0.003	-0.133

As before all three specifications are one way fixed effects models. Two way models were rejected decisively in this case on the basis of the chronic multicollinearity that was induced when both time and firm dummies were employed. The previous arguments concerning transparency and the focus on cross sectional variation rather than time series evolution do still hold.

For the reasons given for previous models fixed effects were again preferred. This time the Hausman test statistic confirmed the choice more clearly. Table 4.4 presents models adjusted once more for the effects of first order autocorrelation. The autocorrelation coefficient, ρ, for unadjusted models suggested that a Cochrane Orcutt adjustment should be made[98] so degrees of freedom were traded for improved diagnostic statistics.

Many parallels may be drawn between the above and Table 4.3. Diagnostic statistics are satisfactory, in particular the problem of first order autocorrelation appears to have been mitigated. The output term (Y) in entering significantly in model 2.1 notably takes the opposite sign to that in models 1.1 and 1.1h. However price terms included are in line with a priori expectations, correctly signed and significant. Multicollinearity again becomes a problem with two or more price terms. Of the hedonic variables employed before, Z2 enters 2.1 correctly signed, and Z5 enters 2.3 as it did 1.2h and 1.3h.

Of the other variables, length of mains raises average cost whilst area has a depressing effect presumably due to the reduced infrastructure maintenance involved in sparsely populated, sparsely served areas. The curious coefficient estimate is that attached to total number of employees. For model 1.1 the term enters as expected, but this is reversed in 1.2 and 1.3. This counterintuitive result may be partly explained by noting that the inclusion of capital cost in average cost, effectively swamps the total wage bill. It may be argued that some substitution effect is being picked up here. Consequently the addition of labour units may reduce capital input, and as this comprises the overwhelming part of average cost the coefficient takes the

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[98] Values of ρ for three unadjusted models were 0.414, 0.523 and 0.611 respectively.

negative sign.

Efficiency: The Rudimentary Approach.

All the techniques and caveats discussed for the theoretically sound models carry over to this more rudimentary approach. Table 4.4F represents the adjusted intercepts terms for fixed effects panel data frontier estimation. For model 2.1 firm 4 lies on the frontier; for models 2.2 and 2.3 it is again firm 18 that apparently has the lowest unit cost.

Table 4.4F

FIRM	MODELS		
	2.1	2.2	2.3
	$\hat{u}_i = \hat{\alpha}_i - \min_i (\hat{\alpha}_i)$		
1	4.7422	1592.8090	12735.6891
2	14.3487	638.1729	3760.5386
3	7.4635	75.5707	5343.5287
4	0.0000	1068.6353	16563.5419
5	8.1228	1428.4155	10524.8516
6	8.0991	1435.3981	28113.0860
7	16.7451	1896.1067	5392.1454
8	17.5122	2355.8524	13393.4449
9	12.5722	1694.5502	11760.4849
10	15.0525	1014.1409	13096.8725
11	27.6840	558.7591	11931.739
12	27.1378	1071.7760	9600.4798
13	31.4371	965.3369	17739.2050
14	36.4111	1686.9854	12077.4155
15	25.9864	87.6342	22961.1940
16	34.0602	2169.2233	15541.7141
17	45.6011	1805.2795	24478.7455
18	3.6782	0.0000	0.0000
19	37.2234	995.0247	28744.4750
20	9.5666	1729.8684	11740.9812

From these residuals an ordinal 'efficiency' ranking may be derived.

Table 4.4R

	MODELS		
	2.1	2.2	2.3
FIRM	RANK		
1	3	13	12
2	9	5	2
3	4	2	4
4	1	9	16
5	6	11	6
6	5	12	7
7	11	18	3
8	12	20	14
9	8	15	9
10	10	8	13
11	15	4	10
12	14	10	5
13	16	6	17
14	18	14	11
15	13	3	18
16	17	19	15
17	20	17	19
18	2	1	1
19	19	7	20
20	7	16	8

Lowest cost=1
Highest cost=20

Spearman's coefficient of rank correlation may be derived from the results as before.

Table 4.4S Spearman's Coefficient of Rank Correlation.

Models	r
2.1 and 2.2	0.2361
2.2 and 2.3	0.1699
2.1 and 2.3	0.5293
1.1h and 2.1	0.9368
1.2h and 2.2	0.4015
1.3h and 2.3	0.8647

Notable here is the fact that models 2.1 and 2.3 show good positive correlation, whilst the historic specification appears to be more idiosyncratic. Of greater interest is the comparisons that may be drawn between these rankings and those obtained from the theoretically sound models. Rankings from models 2.1, 2.2 and 2.3 appear to have remarkably high degrees of positive correlation with 1.1h, 1.2h and 1.3h. The result appears to confirm the inclusion of hedonic terms in the cost function specification. Indeed, setting aside the niceties of duality theory does not appear to be as disruptive of ranking as might be assumed. The difficulties of working in a theoretical vacuum remain, as do all previous caveats, and should not be minimised. Nevertheless the results are encouraging from the point of view of achieving some consistency in the rankings. One may tentatively conclude that these results suggest that comparative efficiency measurement using regression techniques is feasible and does give results which are moderately robust in terms of econometric technique.

Banding the firms as before the results are as follows.

Table 4.4B. Efficiency Banding for Models 2.1, 2.2 and 2.3.

Band 1 Firms (low cost): 2, 3, 18

Band 2 Firms (intermediate): 1, 4, 5, 6, 7, 9, 10, 11, 12, 13, 15, 19, 20.

Band 3 Firms (high cost): 8,14,16,17.

To confirm our contention that the results from this analysis are fairly robust we would desire very few changes in the bandings for the firms. In fact firms 6, 8 and 9 drop one band, whilst firms 11 and 13 rise.

Conclusions.

In summary, we may conclude that employing the tools of econometrics it is indeed possible to arrive at an ordinal ranking of companies that, however imperfectly, gives some indication of the comparative efficiency of firms. Moreover, the results appear to be moderately robust with respect to the particular estimation method employed. And although some changes in ordering are observed when theoretically sound specifications are given up, these are not generally so great as to distort the overall picture.

The second conclusion is that price factors are not the crucial element in determining the specified cost functions. In modelling production, the effects of price seem to be swamped by the effects of physical conditions which are captured by the hedonic variables. In this we may be picking up merely the effect of greater cross sectional variation in hedonic as against price terms, although this seems unlikely given that Pl does exhibit some variation; certainly as much as other non price variables which appear in the reported functions. When the RPI price index is included models suffer from severe multicollinearity. This may be due, in part, to firms under public ownership being allowed to let prices track the index rather than be tied rather more closely to cost. Clearly, from a policy point of view it would be appropriate to break or weaken this link in some way. For whilst the costs of water companies do track the RPI to a certain extent the relationship is not perfect.

The first set of (theoretically sound) results also appear to confirm the view that operational economies of scale in the English and Welsh water industry are largely exhausted at the current level of activity. This is in line with previous studies (discussed in Chapter 3) which have noted that economies of scale are exhausted at a fairly low level for the collection and treatment functions. The policy implication is that there should be no general presumption in favour of the further merger of companies in the industry. This would appear to imply that consumers are not at any significant cost disadvantage by virtue of the fact that they are served by statutory companies. The reverse may be the case; although we are unable to come to firm conclusions for public and private companies in this study.

Unsurprisingly, the cost of capital and valuation of capital stock have arisen as key determinants of overall cost. Under both the historic cost and current cost accounting conventions, the cost of capital swamps any measure of operating cost. However it is clear that historic cost measures of capital stock are at best unreliable, and at worst completely misleading. Therefore, in interpreting the results for regulatory purposes this is an issue which should command the closest attention.

In general, the methods presented above appear to be tractable for a regulator operating a system of yardstick competition. By giving more information on comparative efficiency the presumption is that the final regulatory arrangements will be improved in and through this work. In general terms, if the work were to be applied to industries such as electricity and gas the analysis has shown that capital cost provides the greatest challenge to the system. Agreement over the conventions to be adopted and the acquisition of reliable data are important prerequisites. Furthermore, the question of 'explanatory factors' or the modelling of heterogeneity has profound implications for any regulatory solution. Accurate modelling of these appears to be rather more important than the modelling of the various price terms.

Overall, the analysis presented in this chapter has gone some way to answering the initial question 'Can Yardstick Competition Work?' in the affirmative.

Appendix 1.Water Supply Companies in England and Wales 1974-89.

Regional Water Authorities:	Identification
* Anglian	1
* Northumbrian	2
* North West	3
* Severn Trent	4
* Southern	5
* South West	6
* Thames	7
* Welsh	8
* Wessex	9
* Yorkshire	10
Statutory Water Companies:	
Bournemouth and District Water Company	
Bristol Water Company	
Cambridge Water Company	
Chester Waterworks Company	
* Colne Valley Water Company	11
East Anglian Water Company	
East Surrey Water Company	
* East Worcestershire Waterworks Company	12
Eastbourne Water Company	
* Essex Water Company	13
Folkestone and District Water Company	
Hartlepools Water Company	
Lee Valley Water Company	
* Mid Kent Water Company	14
Mid Southern Water Company	
Mid Sussex Water Company	
Newcastle and Gateshead Water Company	
North Surrey Water Company	
Portsmouth Water Company	
Rickmansworth Water Company	
* South Staffordshire Water Company	15
* Sunderland and South Shields Water Company	16
* Sutton District Water Company	17
Tendring Hundred Waterworks Company	
* West Hampshire Water Company	18
West Kent Water Company	
* Wrexham and East Denbighshire Water Company	19
* York Waterworks Company	20
Cholderton and District Water Company	

* = indicates companies included in the sample.

Appendix 2. Data Sources.

Primary data sources:
Annual reports of the companies, the Digest of Environmental Pollution and Water Statistics (Dept of the Environment), various CSO publications and 'Water Data', a publication of the discontinued Water Data Unit.

Secondary data sources:
Annual reports and accounts of the National Water Council (dissolved on 30th September 1983 under the terms of the Water Act 1983), 'Waterfacts' (the annual statistical digest of the Water Authorities Association 1984-1989) (Subsequently the Water Services Association 1989-)and the Water Industry Reviews of 1978 and 1982, CSO Guide to Official Statistics, 1990 Edition, Sources of Unofficial UK Statistics, 2nd Edition 1990, Eurostat Index, 4th Edition.
CIPFA 'Water Supply and Sewage Treatment and Disposal Statistics 1979-80 Actuals', CIPFA 'Water Services Charges Statistics 1979/80, 80/1, 81/2, 82/3, CIPFA (1984) 'The Water Industry: United Kingdom Service and Costs 1984.', CIPFA, London.CIPFA (1985) 'The Water Industry: United Kingdom Service and Costs 1985.', CIPFA, London, CIPFA (1986) 'The Water Industry: United Kingdom Service and Costs 1986', CIPFA, London, CIPFA (1989) 'The Water Industry: United Kingdom Services and Costs 1988 and Charges for Services 1989/90' CIPFA, London.
Monopolies and Mergers Commission Reports:
1981: Severn Trent Water Authority, East Worcestershire Waterworks Company and South Staffordshire Waterworks Company (HC 339)
1982: Anglian Water Authority and North West Water Authority (CMnd 8726)
1984: Yorkshire Water Authority (Cmnd 9392)
1986: Southern Water Authority, The Eastbourne Waterworks Company, Folkestone and District Water Company, The Mid Kent Water Company, Mid Sussex Water Company, Portsmouth Water Company and West Kent Water Company. (Cmnd 9765)
1988: Welsh Water Authority (Cmnd 366)
1990: General Utilities PLC and The Mid Kent Water Company (Cmnd 1125)
1990: General Utilities PLC, The Colne Valley Water Company and Rickmansworth Water Company. (Cmnd 1029)
1990: Southern Water PLC and Mid Sussex Water Company (Cmnd 1126)

Appendix 3. Location of Statutory Companies within Water Authority Areas.

RWA Area:	Statutory Companies:
North West	None
Northumbrian	Hartlepools, Newcastle, Sunderland
Severn Trent	East Worcestershire, South Staffordshire
Yorkshire	York
Anglian	Cambridge, East Anglian, Essex, Tendring Hundred
Thames	Colne Valley, East Surrey, Lee Valley, Mid Southern, North Surrey, Rickmansworth, Sutton.
Southern	Eastbourne, Folkestone, Mid Kent, Mid Sussex, Portsmouth, West Kent.
Wessex	Bournemouth, Bristol, Cholderton,West Hampshire
South West	None
Welsh	Chester, Wrexham.

Appendix 4. Classification of Water Suppliers according to New Earnings Survey Regions.

NES Region:	Companies:
Remainder of the South East.	Colne Valley, East Surrey, Eastbourne, Essex, Folkestone, Lee Valley, Mid Kent, Mid Southern, Mid Sussex, North Surrey, Portsmouth, Rickmansworth, Tendring Hundred,West Hampshire, West Kent.Thames WA.Southern WA.
South West.	Bournemouth, Bristol, Cholderton, Wessex WA, South West WA
East Anglia.	Cambridge, East Anglian, Anglian WA.
North.	Hartlepools, Newcastle, Sunderland, Northumbrian WA.
North West.	Chester, North West WA.
West Midlands.	East Worcestershire, South Staffordshire,Severn Trent WA.
Greater London.	Sutton
Yorkshire and Humberside.	York, Yorkshire WA.
Wales.	Wrexham, Welsh WA.

Chapter 4: Technical Appendix.

This appendix contains regression results obtained by re-estimating the models presented in Chapter 4 using the real rather than the nominal rate of interest. Throughout, the real rate of interest is designated PRK, and was calculated by adjusting the original nominal rate of interest, PK (Public Works Loan Board average rate of interest on new advances), by the Retail prices index (PP).

Theoretically, it may be argued that this approach is more satisfactory. It is the real rate of interest that plays an important part in any large commercial organisation's investment decision. However the results obtained using this adjustment, and the conclusions derived from those results were left broadly unaltered after the change. Consequently they are presented as a Technical Appendix to Chapter 4. It may be argued that, in this case, the nominal rate of interest is an acceptable proxy for the real rate.

Apart from its inclusion in the models as a price term, PRK, the adjustment also affected the dependent variables employed. Unit cost was again defined in three ways: as operating cost per unit of output (OPC/Y), as historic valuation operating cost per unit of output (CHRC/Y) and as current valuation operating cost per unit of output (RC/Y). As before, the denominator in each of these terms represents output. The numerators differ.

OPC represents a 'pure' operating cost, excluding any element of capital cost, and is unaffected by the switch from using a nominal to a real rate of interest. CHRC adds into the operating cost a proxy for the working cost of capital. This capital cost is obtained by multiplying the net book value of fixed assets at their historic cost (FIXA) by the price of capital, which we proxy by PRK. The capital charge is simply (FIXA x PRK) and this is added to OPC to give CHRC. The third measure RC is obtained by adding to OPC a capital charge of (CCFA x PRK); ie the current gross replacement cost of tangible fixed assets multiplied by the real interest rate. Hence, instead of working with dependent variables (OPC/Y), (CHC/Y) and (C/Y), we worked with (OPC/Y), (CHRC/Y) and (RC/Y).

The two approaches to testing adopted in the chapter were repeated: the modelling strategy employing the translog cost function and its variants, and the 'rudimentary' modelling strategy.

Models Employing the Translog Cost Function.

As before, a general to specific testing strategy was adopted. A translog unit cost function in four input prices was constructed and restricted in the ways discussed earlier, to test for homogeneity, homotheticity and unitary elasticity of substitution. As before, tests of the restrictions were ill defined, inconclusive and contradictory. Thus reported models were arrived at by accepting only well defined models with parameter estimates broadly consistent with economic theory. As before, Cobb Douglas functions in two input prices gave the most satisfactory results. These are reported below in Table 4.3T.

Table 4.3T One Way Fixed Effects Models Adjusted for First Order Autocorrelation.

Models 1.2T and 1.2hT Dependent Variable = Ln(CHRC/Y) - LnPl
Models 1.3T and 1.3hT Dependent Variable = Ln(RC/Y)-LnPl

	MODEL			
EXPLANATORY VARIABLE	1.2T	1.2hT	1.3T	1.3hT
lnY	3.2792§	3.1897§	3.2762§	3.6818§
	(1.6920)	(1.7150)	(1.8030)	(1.9540)
ln(Prk/Pl)	7.4659‡	7.5985‡	8.6326‡	8.7146‡
	(0.3373)	(0.2981)	(0.3941)	(0.3536)
lnZ1				
lnZ2		15.1410‡		16.6180‡
		(2.8940)		(3.3690)
lnZ5		32.9390‡		36.5870‡
		(5.2150)		(6.1630)
D1	10.2027	-33.3104†	18.0315	-35.6985†
	(13.4473)	(15.5418)	(14.5389)	(18.0693)
D2	12.2455	-35.2366†	19.9839	-37.5021†
	(12.3735)	(14.3356)	(13.3282)	(16.7179)
D3	6.7633	-39.6076†	14.5519	-42.4135†
	(15.0407)	(16.2271)	(16.1816)	(18.8679)
D4	8.2125	-33.5385†	16.0168	-35.6578†
	(14.4319)	(15.6275)	(15.5292)	(18.1459)
D5	12.7882	-33.8001†	20.3109	-36.0849†
	(12.3804)	(14.0515)	(13.3356)	(16.3866)
D6	14.1298	-33.1193†	21.9419§	-35.2681†
	(11.6418)	(14.5086)	(12.5462)	(16.9129)
D7	6.5282	-34.1004†	14.3830	-36.0371†
	(15.0805)	(15.5855)	(16.2251)	(18.0934)
D8	10.9345	-29.4542§	18.7219	-31.2602§
	(13.1792)	(15.2296)	(14.1889)	(17.6804)
D9	14.9048	-28.7699†	22.6645§	-30.3997§
	(11.2691)	(13.8163)	(12.1475)	(16.0937)
D10	9.4679	-34.4465†	17.1245	-36.8102†
	(13.8549)	(15.3063)	(14.9131)	(17.7979)
D11	17.4552§	-37.8587‡	25.2264†	-39.9134‡
	(10.0505)	(12.4434)	(10.8464)	(14.6321)
D12	21.9726‡	-28.5924†	29.7234‡	-29.8598†
	(7.9182)	(11.4115)	(8.5734)	(13.4227)
D13	14.4399	-32.4622†	22.3946§	-33.9669†
	(11.5592)	(13.0265)	(12.4606)	(15.2259)
D14	18.9335†	-27.7183†	26.6285‡	-29.1076†
	(9.5448)	(12.2807)	(10.3077)	(14.3732)
D15	14.6204	-32.5617†	23.0577§	-33.5679†
	(11.2299)	(12.8401)	(12.1074)	(15.0157)

D16	18.8919†	-44.5049‡	26.4178†	-47.6362‡
	(9.5379)	(13.0118)	(10.3000)	(15.3566)
D17	22.3098‡	-36.8831‡	30.2772‡	-38.5019‡
	(8.0089)	(11.5318)	(8.6713)	(13.6323)
D18	20.1139†	-31.5959‡	28.0745‡	-33.0576†
	(8.5831)	(12.1392)	(9.2834)	(14.2610)
D19	22.9567‡	-29.6629‡	31.5738‡	-30.2529†
	(7.4091)	(11.5093)	(8.0319)	(13.5521)
D20	22.7884‡	-24.7433†	30.2865‡	-25.6296†
	(7.5421)	(10.4107)	(8.1738)	(12.2589)
Adj R^2	0.725	0.794	0.721	0.781
F	23.481	30.971	23.009	28.706
ρ	0.027	0.019	0.013	0.015
Returns to Scale	0.234	0.238	0.233	0.214

§ denotes statistical significance at the 90% level
† denotes statistical significance at the 95% level
‡ denotes statistical significance at the 99% level

This table gives results for four models 1.2T, 1.2hT, 1.3T and 1.3hT. They correspond to models 1.2, 1.2h, 1.3 and 1.3h of Table 4.3 in the main text. The only alteration in terms of data is that the real rate of interest (PRK) is employed instead of PK. The dependent variables as well as the price terms are affected by the change. It should also be noted that no models corresponding to models 1.1 and 1.1h of Table 4.3 are reported here. These were models in which the dependent variables reflected only a 'pure' operating cost. Unsurprisingly the new price term, PRK, did not enhance the explanatory power of these models in any way. Rather than reproducing models 1.1 and 1.1h in the above table, these results are omitted.

All the models reported in Table 4.3T are one way, fixed effects models adjusted for first order autocorrelation. As before, two way models suffered multicollinearity and proved too demanding in terms of degrees of freedom. In addition, first order autocorrelation proved to be a serious problem, and was dealt with, using a Cochrane-Orcutt transformation. Once completed, the diagnostic statistics suggested that the problem had been dealt with in a satisfactory way.

But despite the very similar preferred functional forms, some minor revisions to the models were made. Whilst the non-hedonic models 1.2T and 1.3T had the same functional form as their counterparts 1.2 and 1.3 (Table 4.3), the preferred hedonic models 1.2hT and 1.3hT differed from 1.2h and 1.3h in including the term LnZ2 in preference to LnZ1. The change leads us to reexamine and compare the new results with the old, and to make minor amendments to the analysis.

In both models 1.2hT and 1.3hT the term LnZ2 enters positively and significantly. This suggests that as population density increases the cost of supply increases. This is consistent with the observation that more densely populated areas require more extensive capital infrastructure and hence capital maintenance. There are, of course, large costs associated with the installation, repair and maintenance of water supply infrastructure in densely populated, urban areas.

The other difference in the results that may be noted is that the output term now takes a positive and significant sign throughout. This is a reversal of its position in models 1.2 and 1.3. The implication is that the industry is in a region of decreasing returns to scale and confirms the assertion made previously (and later in Chapter 7) that it is possible that economies of scale have largely been exhausted in the industry at the current size and scale of activity.

The final comment on these results confirms their similarity with those derived earlier. Namely that the price terms are correctly signed and significant at the 99% level as before. Diagnostic statistics are also satisfactory, despite a slight deterioration in the adjusted R^2.

The following two tables now extend the analysis. Table 4.3FT reports the adjusted residuals derived from the estimated firm dummy (intercept) terms. Again, a higher intercept value suggests a higher unit cost. Table 4.3RT orders the intercepts giving a rank for each model. Rankings are one to twenty; one representing the lowest unit cost firm for the model and twenty the highest.

Table 4.3FT

FIRM	MODELS			
	3.1	3.1h	4.1	4.1h
	$\hat{u}_i = \hat{\alpha}_i - \min_i (\hat{\alpha}_i)$			
1	3.6745	11.1945	3.6485	11.9377
2	5.7173	9.2683	5.6009	10.1341
3	0.2351	4.8973	0.1689	5.2227
4	1.6843	10.9664	1.6338	11.9784
5	6.2600	10.7048	5.9279	11.5513
6	7.6307	11.3856	7.5589	12.3681
7	0.0000	10.4045	0.0000	11.5991
8	4.4063	15.0507	4.3389	16.3760
9	8.3767	15.7350	8.2815	17.2365
10	2.9397	10.0583	2.7415	10.8260
11	10.9270	6.6462	10.8434	7.7228
12	15.4445	15.9125	15.3404	17.7764
13	7.9117	12.0427	8.0116	13.6693
14	12.4053	16.7866	12.2455	18.5276
15	8.0923	11.9432	8.6747	14.0683
16	12.3637	0.0000	12.0348	0.0000
17	15.7816	7.6218	15.8942	9.1343
18	13.5857	12.9090	13.6918	14.5786
19	16.4285	14.8420	17.1908	17.3833
20	16.2602	19.7616	15.9035	22.0066

Table 4.3RT

FIRM	MODELS			
	3.1	3.1h	4.1	4.1h
	RANK			
1	5	10	5	9
2	7	5	7	5
3	2	2	2	2
4	3	9	3	10
5	8	8	8	7
6	9	11	9	11
7	1	7	1	8
8	6	16	6	15
9	12	17	11	16
10	4	6	4	6
11	13	3	13	3
12	17	18	17	18
13	10	13	10	12
14	15	19	15	19
15	11	12	12	13
16	14	1	14	1
17	18	4	18	4
18	16	14	16	14
19	20	15	20	17
20	19	20	19	20

Lowest Cost Rank = 1
Highest Cost Rank = 20

The most obvious difference from the results in the main text is that firms lying on the frontier are now firms 7 and 16 rather than 3 and 18. But to analyse the results further, Spearman coefficients for various pairs of rankings are reported below.

Table 4.3ST Spearman's Coefficient of Rank Correlation.

Models	r
1.2T and 1.2hT	0.5647
1.3T and 1.3hT	0.4481
1.2T and 1.3T	0.9984
1.2hT and 1.3hT	0.9909
1.1 and 1.2T	0.8842
1.1 and 1.3T	0.8872
1.1h and 1.2hT	-0.0090
1.1h and 1.3hT	0.0195

As in Table 4.3S there is a degree of positive correlation between the nonhedonic and hedonic versions employing the same cost of capital. In addition models 1.2T / 1.3T and 1.2hT / 1.3hT are very highly correlated. When considering models 1.1 and 1.1h (models with operating cost forming part of the dependent variable) the nonhedonic version (1.1) is highly correlated with nonhedonic models 1.2T and 1.3T. The pattern does not, however, hold for hedonic versions. Clearly there, the cost structure is explained in a very different way in the equations including and excluding capital cost. Thus hedonic variables in equations 1.2hT and 1.3hT proxy capital stock in a slightly different way from those included in 1.1h. However, given the fact that there has been a slight change in specification these minor differences do not radically alter the overall conclusions of the models, as can be seen below.

Table 4.3BT Efficiency Banding for Models 1.1h, 1.2hT and 1.3hT

Band 1 Firms (low cost) : 1, 2, 3, 4, 5, 10.

Band 2 Firms (intermediate) : 6, 7, 9, 11, 16, 17, 18.

Band 3 Firms (high cost) : 8, 12, 13, 14, 15, 19, 20.

Table 4.3BT corresponds to Table 4.3B in the main text, banding firms according to their relative efficiency in three hedonic models. Despite the change in specification the overall pattern remains the same. Specifically, the low cost band is completely occupied by the Water Authorities, and the high cost band's composition is mainly drawn from the statutory companies. Some movements have taken place, but at most companies have moved one band between tables 4.3B and 4.3BT. No company has moved from the low cost band to the high cost band or vice versa. One movement is, however of note. Firm 18, which was a clear outlier in table 4.3B now joins other statutory companies in the intermediate band.

Overall, the results again confirm the finding of Lynk (1993), that the RWA's operated at lower levels of inefficiency than privately owned companies.

A Rudimentary Modelling Approach.

Again setting aside the strict constraints of duality theory in the construction of the cost function, reestimation occurred with the rudimentary modelling approach. This time variables entered or left the regression according to whether or not they had a significant influence on the overall fit of the equation.

Using panel data with one and two way, fixed and random effects models, the following preferred specifications were obtained.

Table 4.4T One Way Fixed Effects Adjusted for First Order Autocorrelation

Model 2.2T Dependent Variable = CHRC/Y
Model 2.3T Dependent Variable = RC/Y

	MODEL	
EXPLANATORY VARIABLE	2.2T	2.3T
Y	-0.8232	3.2408†
	(0.5245)	(1.3980)
PRK	132.8600‡	922.7400‡
	(4.6180)	(36.4200)
Z5		371.8000
		(271.1000)
AREA	-0.1039§	
	(0.0565)	
MAIN	0.1396‡	
	(0.0489)	
EMPL	-0.0852†	-0.6292‡
	(0.0389)	(0.2352)
GDWT	-1.9956	2.5063
	(3.7660)	(20.7500)
D1	91.9561	-1905.2499
	(611.1365)	(3790.4234)
D2	-42.8249	-4669.0093§
	(185.4197)	(2509.8047)
D3	-795.9535	-5094.6694
	(649.5982)	(4393.3958)
D4	-449.4034	-1350.1325
	(626.6950)	(3911.9429)
D5	165.8694	-2705.5185
	(358.4819)	(2786.1702)
D6	105.9569	-3050.7412
	(285.9312)	(3518.9328)
D7	332.0338	-4432.6946
	(686.4124)	(4292.8338)
D8	591.6144	-2203.1082
	(603.1760)	(3345.2863)
D9	464.8919	-2571.9762
	(374.8319)	(3444.7656)
D10	-345.7455	-2443.6428
	(444.2497)	(3173.5962)
D11	69.2436	-2427.1644
	(319.7420)	(2227.3709)

D12	260.2997	-3586.7820
	(398.8443)	(3311.4767)
D13	-111.4454	-1481.7770
	(130.0777)	(1620.2865)
D14	336.2499	-2864.7991
	(365.6902)	(3134.4692)
D15	-134.2588	115.0655
	(245.9115)	(2022.1793)
D16	226.0829§	-1606.2857
	(130.3689)	(1751.3427)
D17	443.9983	650.0639
	(413.9836)	(2711.7302)
D18	-170.8643§	-5368.4604§
	(94.8574)	(2856.7943)
D19	60.8394	1223.5554
	(106.5328)	(2978.6209)
D20	186.5082†	-2802.3864
	(81.6240)	(1808.4883)
Adjusted R^2	0.873	0.818
F	49.983	34.422
ρ	0.185	0.087

The preferred models are one-way fixed effect models; two way models were again rejected on the basis of chronic multicollinearity. First order autocorrelation was also diagnosed, and remedial action taken in the form of a Cochrane-Orcutt transformation.

Comparing equations 2.2T and 2.3T with their counterparts in the main chapter (2.2 and 2.3) the similarities are striking. Excluding dummies, all variables have the same sign, and all those significant at or above the 90% level are the same in both cases. The only exception to this rule is Z5, which was significant at the 99% level in equation 2.3 but was not in equation 2.3T. In general the adjusted R^2 terms have improved, from 0.749 in model 2.2 to 0.873 in model 2.2T; and from 0.659 to 0.818 for models 2.3 and 2.3T. These results mean that all the comments for models 2.2 and 2.3 carry over directly. So we may again note that all the price terms are correctly signed and significant, and that as before the coefficient on the term EMPL is negative.

Table 4.4FT reports adjusted intercept terms for fixed effects panel data frontier estimation, and Table 4.4RT the rankings.

Table 4.4FT

	MODELS	
	3.3	3.4
FIRM	$\hat{u}_i = \hat{\alpha}_i - \min_i(\hat{\alpha}_i)$	
1	887.9101	3463.2100
2	753.1291	699.4507
3	0.0000	273.7906
4	346.5506	4018.3280
5	961.8504	2662.9420
6	901.9109	2317.7190
7	1127.9880	935.7654
8	1387.5680	3165.3520
9	1260.8460	2796.4840
10	450.2085	2924.8170
11	865.1976	2941.2960
12	1056.2540	1781.6780
13	684.5086	3886.6830
14	1132.2040	2503.6610
15	661.6952	5483.5260
16	1022.0370	3762.1740
17	1239.9520	6018.5240
18	625.0897	0.0000
19	856.7934	6592.0150
20	982.4622	256.0740

Table 4.4RT

FIRM	MODELS	
	3.3	3.4
	RANK	
1	10	14
2	7	3
3	1	2
4	2	17
5	12	9
6	11	6
7	16	4
8	20	13
9	19	10
10	3	11
11	9	12
12	15	5
13	6	16
14	17	7
15	5	18
16	14	15
17	18	19
18	4	1
19	8	20
20	13	8

Lowest Rank = 1
Highest Rank = 20

Model 2.3T, like model 2.3, has firm 18 lying on the frontier. But model 2.2T replaces firm 18 with firm 3.

Table 4.4ST Spearman's Coefficient of Rank Correlation.

Models	r
2.2 and 2.2T	0.8361
2.3 and 2.3T	0.9639
2.2T and 2.3T	0.0316
2.1 and 2.2T	0.4211
2.1 and 2.3T	0.4541
1.2h and 2.2T	0.1263
1.3h and 2.3T	0.7985

The Spearman coefficients highlight the high degree of correlation between the results obtained in models 2.2 / 2.3 and those in models 2.2T / 2.3T. Other patterns are repeated. For example: as 2.2 and 2.3 showed very little positive correlation so do 2.2T and 2.3T; 1.3h and 2.3T are strongly positively correlated as were 1.3h and 2.3.

The extent to which the results are similar may be confirmed by examining the efficiency banding for models 2.1, 2.2T and 2.3T.

Table 4.4BT Efficiency Banding for Models 2.1, 3.3 and 3.4.

Band 1 Firms (low cost) : 2, 3, 18.

Band 2 Firms (intermediate): 1, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 19, 20.

Band 3 Firms (high cost): 8, 16, 17.

Comparing the results of Table 4.4B with 4.4BT the only difference is that firm 14 has moved from band 3 to band 2.

Conclusion.

By using the real rather than the nominal rate of interest and reestimating the various cost functions, it has been demonstrated that the new results obtained are very much in line with those presented before. The database lacks cross sectional variation in terms of the key price variables, and this modification is unable to meet that deficiency.

Consequently, the conclusions of Chapter 4 remain largely unaltered; and it confirms that this change in a key variable has only a modest effect on the results.

Chapter 5.

Comparative Efficiency Measurement: Sewage Treatment and Disposal in England and Wales.

Introduction.

The second context for comparative efficiency measurement is the sewage treatment and disposal industry in England and Wales. An industry which has aroused little interest among economists, despite delivering one of society's oldest and most essential services. Its subordinate position to water supply on research agendas is well illustrated in the work of Ofwat. For although both water and sewerage functions fall within the regulatory remit, research on comparative efficiency measures is considerably more advanced for the former.[99]

This chapter complements the previous one, by presenting results of the econometric estimation of a series of cost functions for sewage treatment and disposal in England and Wales: the other primary function of the Water Authorities (since 1989 the Water and Sewerage Companies). But, as before, the physical processes of sewage treatment and disposal will be discussed first; followed by an outline of the institutional development of the industry and the process of modelling and estimation. Conclusions and policy implications round off the chapter.

Physical Attributes and Processes.

The health hazards attached to water borne pollution and the noxious qualities of effluent create the need for the collection, transport, treatment and disposal of foul

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[99] See for example Price (1993) 'Comparing the Cost of Water Delivered', Ofwat Research Paper Number 1.

flows. The water industry is concerned chiefly therefore with just one component of general waste matter. A component labelled by Downing (1969) as sewage; and said to include organic waste material and used water including storm sewage and overland run off from rainfall.[100]

Sewage may be characterised in terms of its volume and pollutional strength. Volume is straightforwardly measured as sewage flow. But a two-dimensional classification of pollutional strength is adopted; biochemical oxygen demand (BOD) and suspended solids (SS). Biochemical oxygen demand is a measure of the biodegradable organic matter contained in sewage. The breakdown of organic matter by biological organisms uses up oxygen from the water. Reductions in the level of dissolved oxygen in water below critical levels will damage many micro-organisms, kill off fish, and generally upset the ecological balance. Consequently a higher level of BOD indicates a higher level of pollution. [101] Suspended solids, is a measure of particulate matter found in sewage. This picks up pollutants such as fine grit, insoluble metal precipitates and other solid matter in liquid suspension not entering the BOD measure. In total this is the raw material that water companies must deal with.

As mentioned above, their dealings involve collection, transmission, treatment and disposal. And whilst the focus of this chapter is on treatment and disposal alone, some

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[100] Other categories of waste matter defined by Downing (1969) include rubbish (general inorganic, solid wastes) and garbage (food wastes of home or industry).

[101] The measure was used in the work of the Royal Commission on Sewage Disposal (1912) who suggested that rivers could be classified according to BOD.

mention should be made of the preceding stages.[102]

Over 96% of households in England and Wales are connected to public sewers. Therefore this network of pipes and conduits is the primary means of sewage collection and transmission. [103] Foul flows and stormwater-run-off enter dedicated or combined sewers designed to accept some multiple of 'dry weather flow' (DWF)[104]. Following storms, large sudden extraordinary flows are encountered, thus sewers designed to receive up to six times their dry weather flow are quite common. Sewerage systems generally work under gravity flow, being laid deeper than water mains and having outfalls and treatment works at the lowest point in the system. Where this is not possible, or the cost of laying sewers at a great depth becomes prohibitive , sewage pumping stations are constructed to maintain the flow.

Problems of toxicity and the risk to public health quickly multiply when sewage is transported over long distances or stored for any length of time. This, combined with the ability to discharge effluent into many river and coastal locations has reinforced the tendency towards localised sewerage and sewage operations. This contrasts with potable water which can be transported for long distances and stored for long periods without the risk of septicity. A final problem with a sewerage system working under gravity at below capacity is that structural decay takes longer to emerge for sewers than for water mains. But potentially the effects are more hazardous with the risk of groundwater

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[102] Much of this discussion is based on information supplied by the Water Services Association.

[103] Table 5A, Waterfacts 1992, Water Services Association.

[104] Dry weather flow (DWF) is the average daily volume calculated from the total sewage flow reaching the works on any working day following seven successive dry days. A dry day is a day in which less than 0.01 of an inch of rain falls.

supply contamination.

The vast majority of sewage put into sewers is taken to sewage treatment works[105], however there remains some variation in the sophistication and extent of this treatment. Generally, works operate below capacity being designed to handle sudden large increases in flow due to surfacewater run off and infiltration. The general pattern of treatment is one in which physical separation (the removal of suspended solids) is combined with the augmentation of natural processes to reduce harmful organic and chemical substances (reduction in BOD). The first stage of treatment is generally a preliminary screening to remove large debris and grit. In this, untreated sewage passes through a screen which collects rags, paper, wood and plastic. These gross solids are usually burnt in incinerators or buried in appropriate landfill sites. By reducing the speed at which sewage passes through the various channels and tanks various suspended solids may be removed. In this primary sedimentation they fall to the bottom forming a sludge which is collected for disposal. The remaining 'settled sewage liquor' may be discharged or sent on for further treatment.

Secondary biological filtration, or activated sludge treatment, reduces the BOD/SS count by aerobic digestion and further settlement. Both methods make use of naturally occurring bacteria to break down organic substances and remove ammonia. The familiar round ponds at sewage works are the site of bacteria bed filtration where the settled sewage liquor is passed over a deep bed of small stones and other materials from either fixed or moving arms. The organisms living in the gaps between the stones feed on the sewage as it passes through. The activated sludge method

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[105] Table 5A, Waterfacts 1992, Water Services Association.

involves sewage liquor being piped into tanks containing micro-organisms that feed on waste particles. Air is forced into the tanks by compressors to maintain an adequate oxygen supply. Secondary treatment often reduces the BOD measurement by over 90%, although there is a good deal of variation in the level of treatment. The effluent is then discharged or passed on to the tertiary filtration and final sedimentation stage. Although most harmful organisms have been removed, this tertiary treatment involves further settlement, chemical operations to remove nutrients (such as phosphates and nitrates) and continued action of the activated sludge. The liquor may be recycled back to the previous stage to be used again or discharged.

Sewage liquor and sludge are the two main products of these treatment processes. Both must be returned to the natural environment at some point. Sewage liquor, in its several forms, may be discharged into rivers, estuaries or at sea[106]. The sea in particular has large dilution capacity and there is good bactericidal action of sunlight and salt water. With well designed long sea outfalls no harmful pollutants should be washed back to shore.

Sludge is the generic term given to treatment residue. Its composition varies depending on area and population reflecting local dietary habits, household and industrial activities. At the works it is commonly over 90% water; but of the dry matter approximately 50-75% is organic, 5-10% grease and the remainder a cocktail of nitrates, phosphates and trace metals. Sludge retrieved from the various stages of treatment has slightly different qualities. Thus, primary sludge is solid matter settled out at the primary

[106] EEC environmental directives such as 76/160/EEC Quality of Bathing Water, have lead to long sea outfalls becoming the preferred method of sea disposal. See also Tables 5N and 5O, Waterfacts 1992, Water Services Association, on discharge statistics.

sedimentation stage of sewage treatment, humus sludge consists of solid matter settled out in special sedimentation (humus) tanks from the treated effluent, and activated sludge is the microbe-rich effluent used to treat incoming sewage in the secondary treatment process by digesting organic matter. Raw sludge being only 2-3% dry solids may be treated further. Thickening reduces the volume by removing much of the water, digestion involves the action of bacteria in anaerobic conditions reducing smell and the number of harmful organisms present. Cold digestion takes two to three years in tanks or lagoons, heated digestion reduces this time to about a month. Final dewatering produces a cake of dried sludge which can be bagged and sold. According to 1989 figures of the dry sludge disposed, approximately 51% was used in agriculture, 22% disposed of at sea, 11% in landfill sites and 7% in incineration.[107] The balance will alter somewhat as sea disposal is phased out.

Institutional Development.

So much for the physical processes. But what of the institutional arrangements used to deliver sewerage services? How did they develop?

The industrial revolution in England and Wales brought with it a rapid increase in the urban population and problems of public health. Frequent outbreaks of cholera and other water borne diseases made the improvement and extension of sewerage and sewage disposal systems a legislative priority, once the cause of the problem had been identified.[108] Various nineteenth century health acts

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[107] Table 5B, Waterfacts 1992, Water Services Association.

[108] Chadwick's (1842) report was influential in prompting sanitary legislation.

addressed the problem[109] but improvements came about slowly, and at the turn of the century many streams and rivers were little more than open sewers.

A significant advance was made in the 1936 Public Health Act which consolidated and extended the previous provisions and made it,

> "...the duty of every local authority to provide such public sewers as may be necessary for effectually draining their district for the purposes of this Act, and to make such provision, by means of sewage disposal works or otherwise, as may be necessary to effectually dealing with the contents of their sewers."[110]

Thus over 1400 local authorities in the form of county boroughs and district councils became responsible for the collection, transport, treatment and disposal of sewage waste in their area. Whilst a few subsequently combined their treatment facilities and operations the movement towards consolidation was much slower than for potable water suppliers. On the eve of the 1974 reorganisation there remained 134 local authority operations, 27 joint sewage authorities, the Greater London Council and the City of London. No privately owned sewerage companies offered a local public service in any area.

The 1973 Water Act radically altered the face of the industry with the ten newly established Regional Water Authorities taking over responsibility for sewerage, sewage treatment and disposal in their area. Under section 15 of the Act it was open for the various local authorities to act as agents of the Water Authorities in continuing to operate and maintain the sewerage system. Many did; however certain trunk sewers, pumping stations, all sewage

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[109] Public Health Acts and amendments 1848, 1872, 1875, 1890, 1907, 1925.

[110] Public Health Act 1936 s14 [ch49 p10]

treatment works and coastal outfalls became the direct responsibility of the water authorities who also operated and maintained sewerage systems where local authorities chose not to do so. Throughout the following decade the scope of environmental legislation directly impinging on the Water Authorities widened, as UK statutory requirements [111] were supplemented by EEC directives.[112] In addition the deterioration of the sewerage infrastructure began to surface as an issue; the result of sustained underinvestment in an ageing capital stock during the mid 1970's and early 1980's.

Privatisation of the ten English and Welsh Water Authorities in 1989 again altered the industry's institutional structure. Under the terms of the 1989 Water Act, sewage arrangements existing at vesting continued to have effect and could only be varied or brought to an end by agreement or by either party giving reasonable notice. The ten privately owned water and sewerage companies were prohibited from giving such notice with expiry before 1 April 1992, and in many cases agency arrangements with local authorities remained in place. Whilst the private companies' functions were licensed and continued under the regulatory auspices of Ofwat, another statutory body the National Rivers Authority (NRA) was established. It took over many of the regulatory functions of the Regional Water Authorities in respect of the maintenance and improvement of the water environment, responsibility for the issue of consents to discharge into rivers and the independent monitoring of river quality. Consequently the water and

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[111] For example in 1984 The Control of Pollution Act Part II was implemented, allowing public access to information about discharges and allowing private individuals to prosecute water authorities if they broke the conditions of the consents.

[112] For example EEC directive 80/78/EEC (drinking water) and 76/160/EEC (bathing water).

sewerage companies were no longer both 'poacher and gamekeeper' in terms of the issue of pollution consents.[113]

To date, pressure for environmental improvements from Europe and Westminster has continued to increase. The water companies are engaged in substantial programmes of investment to meet these requirements.[114] However the Director General of Water Services continues to be concerned at the impact these more stringent requirements will have on prices. Press announcements have made it clear that he is concerned the quality/price tradeoffs being made by European legislators do not represent those of UK consumers.[115]

Background to the Work.

We now move from a description of the background to the heart of the study itself: a tractable means of comparative efficiency measurement. The proposed methods again involve the econometric estimation of a series of cost functions. A formal presentation of the theory appeared in chapter three and will not be repeated. There are, however, several issues to be considered in applying the theory to sewage treatment and disposal.

At a technical level, the cost function is to be preferred to its dual, the production function. The assumptions of

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[113] Helm (1991) argued that the old system displayed elements of regulatory capture, a consequence being the deterioration of river water quality.

[114] Details on the scale and scope of the industry's investment programme are given in '1990/91 Report on Capital Investment by the Water Companies in England and Wales' OFWAT March 1992.

[115] Ofwat Press Release 20/93, 17th June 1993.

exogenous output and input prices are again deemed appropriate for the following reasons. Firstly sewage works must endeavour to treat all matter sent to it. Companies have very clear responsibilities in this respect; output is considered to be largely outwith the control of management. Secondly, companies are price takers in the factor markets. None is of sufficient size to determine the costs of labour or capital. Cost minimisation is held to be a reasonable behavioural assumption. Under price cap regulation such behaviour is rewarded by the retention of larger profits. Under the pre-privatisation regulatory regime there was a downward pressure on plant costs exerted through a succession of ministerial directives to Water Authorities. It may be argued that these were weak in comparison to post-privatisation pressures, nevertheless they did exist. In addition, substitute sewage treatment and disposal facilities have always existed. In contrast to the case of water supply where the choice of suppliers is very limited indeed, companies and individuals can make other arrangements relatively easily by setting up septic tanks and contracting out disposal services. This reinforces the cost minimising behaviour of sewerage firms.

The choice of the cost function as an analytical device for the study is confirmed by what little econometric literature exists. As mentioned in chapter three, Knapp's (1978) paper remains virtually unique among published work in explicitly modelling the UK sewage treatment and disposal industry. Studies of pollution in general have been more common[116] giving evidence on issues which are only loosely related to the whole question of sewage treatment.

Knapp (1978) employed 1972/3 cross sectional plant level

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[116] See for example Storey (1978), Epple and Visscher (1984) and Pittman (1981).

data, fitting a statistical cost function to a sample of 172 works by ordinary least squares. He drew the conclusion that strong and pervasive economies of scale existed in the operation of the works. Knapp saw his contribution as an early attempt to dispel some of the ignorance surrounding the economic conditions of the production and supply of the service. But the drawbacks to the study were clear. In the specification of the cost function he was driven, through lack of data, to omit input prices, and consequently laid to one side the insights of duality theory linking cost and production functions. Instead average operating cost was the dependent variable regressed upon terms which entered or left the regression on the basis of whether they exerted a significant influence on average cost. The omission of prices and capital costs in the modelling of such a capital intensive industry is clearly a specification error.

This chapter emulates Knapp (1978) in employing more recent sewage treatment and disposal statistics containing the same level of detail. But in many important respects it takes the analysis forward.

Two quite distinct approaches to cost function estimation are taken. The first is the 'data mining' approach of Knapp. He had justified this by arguing that duality results were seldom employed in the early stages of empirical analysis of an industry. Explanatory variables entered and left his cost function on the grounds of whether or not they exerted a significant influence on total or average costs. Using a linear in parameters framework, testing proceeded in seeking an overall 'best fit' in terms of R^2 which was consistent with individual regression coefficients registering some level of statistical significance. A large number of variables were employed in additive and multiplicative combination leading to the derivation of preferred models.

But in this chapter a second approach is taken. In an attempt to set the analysis on a sound theoretical footing, the classical econometric testing strategy used in the previous chapter is adopted once again. In other words, a general model consistent with the postulates of economic theory is formulated and then tested down, in an attempt to achieve model parsimony. All available information is employed where possible.

Both approaches raise concerns expressed by Knapp (1978). The first is that in econometric studies of this kind, endogenous regressors are a problem. They result in biased and inconsistent OLS estimates. However, this may not be so serious in the case of cross sectional estimation, as the cost function itself may be regarded as short run. The volume of sewage treated, capital stock, population served and treatment method may be assumed to be exogenous: inherited from the previous time period and outwith the control of managers. But endogeneity may indeed arise in the context of treatment methods, the degree of treatment being a decision endogenous to the firm.

Since Knapp's study this problem may have receded. The quality of influent is largely exogenous, save where treatment works may refuse trade effluents of exceptional strength. With approved river standards to be met by the discharging plant, the decision over what quality of effluent to discharge has also been taken out of their hands. In short, the problem of endogeneity is reduced to the extent that influent quality is given and effluent quality must meet certain prescribed standards.

The second issue is that of the dependent variable. In this the debate as to whether average or total cost functions should be used remains unresolved. Griliches (1972) and Casson (1973) both pointed to the possible pitfalls in regressing ratio variables as is done in average cost functions; where errors of measurement in the deflating variable may lead to inconsistent parameter estimates. Against this, Feldstein (1967) argued that average cost was less susceptible to undesirable problems of multicollinearity and heteroscedasticity. In the present context, it may be held that the deflating regressor - total daily sewage flow - is measured fairly accurately and that errors would not be expected to be more than a very small proportion of total flow. However, the arguments for and against are inconclusive and both average and total cost functions will be worked, testing for heteroscedasticity where necessary.

Data.

The construction of a database for use in econometric testing was a relatively trivial task compared with the work undertaken for a water supply database in Chapter 4. Data were drawn from the sewage treatment and disposal statistics 1979/80, published by the Chartered Institute of Public Finance and Accountancy (CIPFA).

In general terms , the database contains information on the operating cost of individual treatment works, the quantity and quality of average daily sewage flows with other features of 150 sewage treatment and disposal works in England and Wales classified by Regional Water Authority area. The outstanding feature of the CIPFA database is its rich detail in terms of quantity and quality of output and other potential determinants of operating cost. (A full list of variables is given in Appendix I.)

Despite this, the database is flawed in two main respects: firstly in terms of missing observations and secondly in terms of bias. Missing observations on gross works costs and average strength of BOD influent for individual plants, led to the removal of eight observations at the outset. These variables were considered so central to the analysis that their omission rendered the observations inadmissible. But the need to retain observations , and hence degrees of freedom, for statistical purposes meant other missing observations on peripheral variables were proxied rather than omitted. Obviously there is a trade off here; but the view was taken that the absence of data on peripheral variables should not lead to its automatic exclusion, particulary if a suitable proxy was available. Thus, where 1979/80 observations were missing, 1978/9 CIPFA figures on the same works were used as a proxy. Other missing values for age of plant, dry weather flow, strength and method of treatment were completed with reference to other works in the same water authority area. In this way the final sample of 142 was arrived at.

The second problem of bias arises because the database includes observations on only the largest operational works of each authority in terms of 'dry weather flow' and 'population served'. This is a two-edged sword. Whilst biasing the sample towards those works of greater capacity, it has the advantage of allowing representation from each authority. This would not have occurred if the survey were based only on the largest operational works nationally. This in turn has implications for the mitigation of heteroscedasticity.

In scope and detail the data available for the cost function analysis mirrors, almost exactly that used by Knapp. Consequently, discussion of variables as potential regressors will draw on this earlier work. Beginning with cost, the dependent variable, two main options are available namely average operating cost per cubic metre of total daily sewage flow in pence, or alternatively total cost over the year. Both these specifications have at their heart operating cost, which includes the costs of labour, power, rent and rates but excludes capital charges such as debt and depreciation. The choice was discussed above.

For output, a central explanatory variable, a wealth of information on volume and quality is available. Volume is represented as total sewage flow per day, which includes measured domestic and trade sewage and storm run off. Quality indicators are even more detailed with treatment level given as the difference in strength between influent and effluent, 5 days BOD at 20 degrees centigrade, COD (Chemical Oxygen Demand) and SS all measured in mg/litre. Lack of data meant the COD measure was dropped, however there is good reason to suppose that there is some degree of overlap between all three measures; and that BOD and SS, in representing important dimensions of domestic and industrial sewage, should be sufficient to indicate the level of treatment. Other dimensions of output influencing cost include the rate of flow and loading factor. Rate of flow is well proxied by the ratio of average daily dry weather flow to average daily total sewage flow, whilst loading may be given, either by the ratio trade effluent to total sewage flow or total sewage flow per head of population.

Finally turning to capital, this is the area in which the database is most woefully deficient. The database contains no explicit measure of capital stock or depreciation. That being said, the problem is mitigated in several ways. Firstly, with cross sectional analysis of the industry, capital stock may be assumed a fixed exogenous variable outwith the control of works management. Given long fixed asset lives the assumption is reasonable. The ratio of capital to operating costs is also very high in such a capital intensive industry, and in excluding the capital component a finer scalpel may be taken to the dissection of industry operating costs. Secondly, information is available as to the age of equipment and type of treatment process, both of which affect operating costs per unit volume of total sewage flow and the amounts of variable inputs used in treatment. The database has information on the date of commencement of operation of works or the date of any major reconstruction. This may be used as a rough capital vintage proxy, capturing part of the influence capital stock has on operating cost. In addition works are classified by method of treatment. Whilst all these measures are not mutually exclusive and it is not possible to identify the treatment load at every stage, dummy variables may be used in combination to assess their influence on operating cost.[117]

Knapp (1978) employs all these variables in combination but by specifically omitting input prices and meteorological data invites the charge of misspecification. Consequently other information is added to the CIPFA dataset: data on annual rainfall (mm) by water authority area and the prices of labour (by area), electricity, rates and the retail prices index.[118] All proxies go some way mitigating the misspecification.

For both estimation methods the base variables listed below were used as regressors separately, in combination and following transformation.

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[117] Appendix II contains a list of purification methods and the dummies assigned to each.

[118] See Appendix III for sources.

Table 5.1.

Base Variables (CIPFA).

AC	Average operating cost per cubic metre of total daily sewage flow (pence).
Q	Total sewage flow (cubic metres per day).
BODI	Average strength of BOD influent (mg per cubic metre)
BODE	Average strength of BOD effluent (mg per cubic metre)
BOD	Proportion of BOD removed in treatment.
SSI	Average strength of SS influent (mg per cubic metre)
SSE	Average strength of SS effluent (mg per cubic metre)
SS	Proportion of SS removed in treatment.
DWF	Ratio of dry weather flow to average sewage flow.
TE	Ratio of trade effluent to total sewage flow.
POP	Total sewage flow per head of population.
YR	Years since works were built or underwent major reconstruction.
DA-DM	Treatment dummies (Appendix II)

Proxy Variables.

RAIN	Annual rainfall (mm) by Water Authority area.
PL	Price of labour.
PE	Price of electricity.
PR	Price of rates.
PP	Retail prices index.

To give a clearer picture of the variables being employed simple descriptive statistics were calculated and are reported in the tables below.

Table 5.2

Base Variables (CIPFA).

VARIABLE	MINIMUM	MAXIMUM	MEAN	STD DEV
AC	0.034	13.805	2.941	1.693
Q	3228	379850	41574	47316
BODI	0.098	0.700	0.272	0.108
BODE	0.002	0.674	0.033	0.068
BOD	0.000	0.994	0.881	0.177
SSI	0.085	0.887	0.330	0.146
SSE	0.004	0.310	0.035	0.040
SS	0.324	0.992	0.884	0.119
DWF	0.465	2.158	0.810	0.179
TE	0.001	1.498	0.133	0.179
POP	0.042	0.927	0.374	0.155

Table 5.3.

Proxy Variables.

VARIABLE	MINIMUM	MAXIMUM	MEAN	STD DEV
RAIN (mm)	640	1389	963	246
PL (pence)	278.2	304.1	294.0	7.1
PE (pence)	2.872	2.872	2.872	0
PR (pence)	95.3	95.3	95.3	0
PP (index)	69.5	69.5	69.5	0

Descriptive statistics give a much clearer picture of the raw data used in the analysis. What is immediately clear is the dichotomy between CIPFA data (Table 5.2) and the proxy variables used (Table 5.3). The first set of variables show considerable heterogeneity compared with the latter. Overall, however, the measures of pollution show a striking degree of similarity. From this we may predict then, that cross sectional variation is fairly limited in many ways, and the regression results should reflect this.

Modelling Results and Diagnostics.

The two basic approaches taken to modelling the cost structure of the sewage treatment and disposal industry will be labelled 'rudimentary' and 'advanced'. The former is similar to that adopted by Knapp (1978) in which variables enter and leave the regression according to their impact on goodness of fit and the statistical significance of individual coefficients. The latter attempts to draw on the various functional forms specified in the literature as being consistent with the basic postulates of economic theory. Under both headings the results of ordinary and frontier cost function estimation are recorded and interpreted.

A Rudimentary Approach.

Proceeding in a similar way to Knapp (1978) a linear average cost model was constructed and estimated by ordinary least squares. The preferred specification is reported in Table 5.4 below. Estimated coefficients are reported with corresponding standard errors in brackets below.

Table 5.4.

Dependent Variable = AC

142 Observations

RECQ = 1/Q

EXPLANATORY VARIABLE	
constant	-0.8781 (0.6960)
RECQ	8.5835‡ (2.3552)
SS	2.9833‡ (0.6383)
DWF	0.6853‡ (0.2614)
TE	3.4275† (1.5192)
POP	-1.6274† (0.7839)
DC	1.5577† (0.6251)
DM	0.5884‡ (0.1954)
DCRECQ	20.2895† (9.5189)
DCBOD	-1.7847‡ (0.5222)
Adj R^2	0.622
F (9,132)	26.76
Breusch Pagan LM	74.40

§ denotes statistical significance at the 90% level
† denotes statistical significance at the 95% level
‡ denotes statistical significance at the 99% level[119]

[119] Note that this labelling convention will be adopted in all following tables.

The estimation procedure was straightforward. Variables having little influence on average cost in terms of t and R^2 were excluded. Most notably the price terms did not enter the equation. Given the structure of the data heteroscedasticity was identified as a potential problem. In order to detect this the Breusch-Pagan LM statistic was calculated (distributed as χ^2)[120]. The value of 74.40 indicated rejection of the null of homoscedasticity and implied that OLS coefficient estimates would be unbiased but not efficient. Remedial action was taken. Consequently corrected results are reported in Table 5.4, where White's consistent estimate of the covariance matrix[121] gives identical coefficient figures but lower standard errors.

The possible problem of multicollinearity was also addressed by considering the classic symptoms: small changes in data giving large swings in parameter estimates despite good F and R^2 statistics and the coefficient estimates having large standard errors. Given the relative magnitudes of R^2 and t multicollinearity was not considered sufficiently problematic to merit remedial measures such as ridge regression or principal components work.

An adjusted R^2 of 62.2% was encouragingly high and slightly better than Knapp's figure of 60.75%. In testing the joint significance of regressors an F (9,132) of 26.76 was enough to reject the null that coefficients were jointly zero. All reported coefficients were of the expected sign. All except the constant were significant at the 95% level; five were significant and the 99% level. In terms of output, RECQ (the reciprocal of output) was positively signed and significant indicating an 'L' shaped average cost curve and hence economies of scale particularly at the lower levels

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[120] Breusch and Pagan (1979).

[121] White (1978).

of output. The inclusion of higher powers of output did not improve the fit.

Price variables were consistent bad performers, wrongly signed and insignificant. Consequently they were omitted from the final specification. This could have been predicted by examining the raw data and noting the lack of cross sectional variation. As a measure of the degree of treatment SS (the proportion of suspended solids removed in treatment) persistently outperformed BOD (the proportion of BOD removed). The tentative conclusion may be drawn that regulation may be more vigorous for works that discharge visibly unsightly effluent to a greater extent than those which discharge equally polluting but less visible effluent with high BOD levels.

In line with a priori expectations the proportion of trade effluent to total sewage flow had a positive effect on average cost, as did the ratio of dry weather flow to total sewage flow (DWF). The latter loading factor indicated that the higher the dry weather content of operations the higher was average cost. Surface water run off may have a diluting effect, consequently works handling large quantities of this particular form of effluent may enjoy reduced costs of operation. In addition, with storm conditions effluent with a higher than normal BOD may be discharged. This may not be reflected accurately in the data reported. The negative coefficient attached to POP (total sewage flow per head of population) reinforces the conclusion of economies of scale in treatment and disposal.

Of the treatment dummies only DC (diffused air activated sludge) and DM (mechanical dewatering by pressing and other methods) enter singly and in multiplicative combination with RECQ and BOD. These particular techniques raised costs, DM being employed more usually in the larger works where there was perhaps a greater diversity of treatment methods. There may be a certain 'water authority' effect being picked up in these dummies for whilst the DM process is used in some plants within all authorities only three share the process represented by DC. However an attempt to pursue this line of reasoning employing three dummy variable terms representing primary, secondary and tertiary treatment, met with little success.

Having examined the results, mention must be made of the battery of caveats, only slightly less daunting than those given by Knapp (1978). Clearly the omission of capital cost, price and technology measures are all serious drawbacks; but for price an attempt was made to proxy the variables, incorporate them in the estimation and only reject them once they had been judged insignificant. However, in estimation it was still not possible to take account of weekly, daily and hourly fluctuations in sewage flow. Nevertheless the estimated function as a short run relationship does represent an approximation to the underlying operating cost function and demonstrates the existence of strong and pervasive economies of scale over a range of output values. This suggests that sewage treatment and disposal may have the characteristics of a local natural monopoly. [122]

Before drawing out comparative efficiency conclusions the analysis is extended in one important way. Following the work of Aigner, Lovell and Schmidt (1977), a stochastic frontier function is estimated. The theory was outlined in Chapter 3. Using the available cross sectional data a stochastic cost function with a non-normal asymmetric

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[122] It is a separate question as to whether there are diseconomies of scale in the collection and transmission of sewage ie sewerage. As yet there is insufficient sewerage data to test the hypothesis.

disturbance is specified. As before the assumption is made that the error term comprises a symmetrical component, normally distributed and a one-sided component with a truncated half normal distribution. Deviations above the cost frontier reflect the sum of both random factors and the firm's inefficiency. This measure may be decomposed to give a value for overall technical inefficiency and technical inefficiency by observation. Thus in contrast to Chapter 4 cardinal measures of inefficiency may be derived for the sample of firms as a whole and on a firm by firm basis.

The conventional testing strategy was followed, with a frontier function specification giving a preferred model as set out in Table 5.5 below.

Table 5.5.

Dependent Variable = AC

142 Observations

EXPLANATORY VARIABLE	
constant	-1.3586 (1.1569)
RECQ	7.6264‡ (1.5708)
SS	1.7795§ (1.0606)
DWF	1.2084† (0.5178)
TE	0.8452 (0.6175)
POP	-0.7643 (0.6266)
DC	0.7498‡ (0.2116)
DM	0.3007§ (0.1726)
Adjusted R^2	0.608
λ	5.8119
σ	1.6648

The maximum likelihood estimation converged quickly for a model similar in specification to the one reported in Table 5.4. The difference being that the two multiplicative dummy terms did not feature. All coefficients were correctly signed as before with five variables significant at the 90% level, three at the 95% level and two at the 99% level.

Again RECQ and DWF performed well. In the process of arriving at the preferred specification SS outperformed BOD as an output measure. Overall, economies of scale in sewage treatment and disposal were confirmed. Additional information was given for this regression in the reporting of frontier parameters λ and σ are reported. These are used in the calculation of efficiency measures.

Efficiency: The Rudimentary Approach.

With the preliminary estimation completed the question of comparative efficiency may be addressed. This may be done by exploiting one of the strengths of the dataset: its presentation of plant level information with national coverage. This implies in turn that the individual works with costs deviating markedly from the level expected, on the basis of volume treated and processes used, may be identified.

The natural choice of comparative efficiency measure for the first model (Table 5.4) is the regression residual. This has two components; statistical 'noise' and 'inefficiency', jointly assumed normally distributed. The two may not be disentangled and consequently the absolute size of the residual has little significance. Nevertheless observations may be ranked according to the absolute size of their residual: positive residuals indicating a higher observed average cost than predicted (suggesting inefficiency), negative residuals the reverse (suggesting greater efficiency). The information contained in an ordinal ranking of this sort is all that is needed in order to construct a set of yardstick comparators.

Observations on the 142 works in the sample are ranked in Table R1 (see appendix). Ranking runs from those with the largest negative residual (the most 'efficient') to those with the largest positive residual. Clearly, given the vagaries of data quality and estimation procedures, a cardinal interpretation of the list is fraught with difficulty. An ordinal interpretation is to be preferred.

The technique may be repeated for the estimated frontier function. But in this case a more satisfactory inefficiency measure may be derived. Setting aside the assumption of normally distributed disturbances, estimates of overall technical inefficiency and technical inefficiency by observation may be derived. At this point, however, the fragility of estimation and the dangers of working in an theoretical vacuum must be borne in mind. Given values of $\lambda = 5.81194$ and $\sigma = 1.66485$, overall mean technical inefficiency may be calculated at 130.9%; remarkably high. Given λ, the ratio of the error term standard deviates, the inefficiency component swamps the two sided component leading to the very high figure. But in contrast to the previous use of residuals to assess comparative inefficiency the cardinal measure of Jondrow et al (1982) is available. Table R2 (see appendix) presents sewage works ranked according to the size of their predicted one sided disturbance.

On inspection, an overall mean technical inefficiency level of 130.9% appears reasonable given results including outliers such as Halifax North Dean, Aycliffe and Leek. However the use of the results as cardinal measures of inefficiency is questionable. And whilst the pressing requirement is merely for ordinal measurement, attention should be paid to these outliers.

Again, on inspection, both models with slightly different specifications and radically different estimation methods, appear to give similar rankings. If this were indeed the case the results would be desirably robust. One formal way of assessing this correlation is by the use of Spearman's rank correlation coefficient r.[123]

For Rank 1 and Rank 2 r = 0.8852 indicating a very high degree of positive correlation. If there is little to choose between models in terms of ranking, the obvious choice would be to follow the frontier model in constructing a workable system of comparative efficiency measurement. From a theoretical point of view the frontier model appears to have slightly more to recommend it.

An Advanced Approach

In answer to one of the more serious criticisms of the Knapp (1978) data-mining approach, a second methodology was employed. Estimation proceeded following the specification of a theoretically sound cost function. To maintain as general a specification as possible, in common with earlier chapters, the transcendental logarithmic cost function was employed.

Beginning with the most general specification further assumptions of homotheticity, homogeneity and unitary elasticity of substitution were made, the appropriate parameter restrictions applied and tested.

A general to specific modelling strategy was used, testing down from the most general translog cost function with four input prices. Two dependent variable specifications were

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[123] Spearman, C (1904) 'The Proof and Measurement of Association Between Two Things'. American Journal of Psychology, vol 15, pp 72-101. r is a non parametric statistic given by:

$$r=1-\frac{6\Sigma d^2}{n(n^2-1)}$$

where d = difference of rank and n = number of observations.

adopted: an average cost per cubic metre of total daily sewage flow and total cost per year, both normalised on the price of labour. Non-hedonic[124] and hedonic[125] specifications were employed at every stage, treatment dummy variables entered in linear and multiplicative combination. Model parsimony was assumed desirable, and results indicating wrongly signed price and output coefficients were rejected as inconsistent with received theory.

Several general observations emerged from the process of estimation. Firstly estimates of the general translog model appeared degenerate. Secondly, the average cost specification performed very badly, suffering severe problems of multicollinearity especially in terms of input prices. This was clearly going to be the case when PL was the only price variable enjoying any cross sectional variation. Thirdly, total sewage flow as a measure of output performed equally badly.

As a result of these early observations the total cost specification (normalised on the price of labour) and three output variables were employed: total BOD removed annually, total SS removed annually and total BOD+ SS mg/litre removed annually. Of these total SS removed outperformed the other two in line with earlier results. However, general to specific testing was not straightforward and the results often contradictory. The outcome was that both the non-hedonic and hedonic preferred specifications were found to be Cobb Douglas in two input prices[126].

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[124] Specifications including only cost, output and price terms.

[125] Specifications including 'technological' conditions, physical attributes etc.

[126] Note that the function, being Cobb Douglas, is globally concave.

Four preferred models are reported below. These correspond to non-hedonic and hedonic ordinary cost function estimates followed by non-hedonic and hedonic frontier estimates.

Table 5.6.

Dependent Variable = Ln C1/Pl ie Gross works cost per year (pence) normalised on price of labour.

Q2 = total SS removed annually

142 Observations.

EXPLANATORY VARIABLE	
constant	-4.6395 (11.5100)
Ln Q2	0.6624‡ (0.0447)
Ln (Pe/Pl)	0.6248 (2.4940)

Adjusted R^2	0.609
$F(2,139)$	110.96
Breusch Pagan LM	1.40

Table 5.6 presents the best non-hedonic specification. The model is clearly rather unsatisfactory. Although after correcting for heteroscedasticity, the output coefficient is significant. This is reflected in an adjusted R^2 of 60.9% and the firm rejection of the hypothesis that all coefficients are jointly zero. From the results no firm conclusions can be drawn about the effect of price terms. This may be a reflection of the lack of cross sectional variation in the database for these variables. This prompts the consideration of the hedonic specification in Table 5.7 below.

Table 5.7

Dependent Variable = Ln C1/Pl

142 Observations

EXPLANATORY VARIABLE	
constant	3.3006 (8.3850)
Ln Q2	0.1785‡ (0.0572)
Ln (Pe/Pl)	1.2299 (1.7890)
Ln DWF	0.3969‡ (0.1026)
Ln POP	0.2327† (0.1015)
Ln LOAD	0.0978‡ (0.0382)

Adjusted R^2	0.789
F (5,136)	106.34
Breusch Pagan LM	4.77

In terms of diagnostic testing the improvement is marked. All coefficients are correctly signed, and all are significant at the 95% level save the price and constant terms. The null of homoscedasticity in disturbances may not be rejected whilst an F of 106.34 and adjusted R^2 of 78.9% are both satisfactory. Again the 'loading variables' DWF and POP are included, POP (or POPU specified in the earlier model) taking a positive sign with total cost as the dependent variable. As noted earlier the output measure Q2 represents total SS removed annually. At this early stage the work confirms the conclusion that the physical characteristics of sewage flow, and sewerage arrangements in general, have a significant impact on costs. Once again, price terms do not enter strongly.

Before examining efficiency implications the counterpart frontier estimates are presented. Table 5.8 being the non-hedonic specification and Table 5.9 the hedonic.

Table 5.8.

Dependent Variable = Ln C1/Pl

142 Observations

EXPLANATORY VARIABLE	
constant	-7.6568 (8.6390)
Ln Q2	0.6614‡ (0.0468)
Ln (Pe/Pl)	0.0594 (1.8030)
λ	1.4315 (0.3328)
σ	0.6668 (0.0646)
Adjusted R^2	0.609

Table 5.9.

Dependent Variable = Ln C1/Pl

142 Observations

EXPLANATORY VARIABLE	
constant	3.3006 (8.3850)
Ln Q2	0.1785‡ (0.0572)
Ln (Pe/Pl)	1.2299 (1.7890)
Ln DWF	0.3969‡ (0.1026)
Ln POP	0.2327† (0.1015)
Ln LOAD	0.0978‡ (0.0382)
$F(5,136)$	106.34
Adjusted R^2	0.789

Most notably, neither specification is improved. Indeed for the frontier hedonic model results are exactly as before. Waldman (1982)[127]has shown that if OLS residuals are positively skewed for the cost frontier, the maximum likelihood estimate for the stochastic frontier model is simply OLS. Thus Table 5.9 and Table 5.7 contain identical results. Nothing further can be added, except to note that this raises the question of incorrect model specification or data which are inconsistent with the model.

[127] Waldman, D (1982) ' A Stationary Point for the Stochastic Frontier Likelihood', Journal of Econometrics, vol 18, pp 275-279.

Efficiency Implications.

Despite their drawbacks, efficiency rankings on the basis of residuals and the Jondrow et al (1982) adjustments may be presented. The appendix contains Table R3 (corresponding to the preferred non-hedonic specification), Table R4 (corresponding to the preferred hedonic specification) and Table R5 (corresponding to the non-hedonic frontier specification).

Once again the residuals in Tables R3 and R4 should be interpreted in a purely ordinal way, whilst those in Table R5 purport to be cardinal measures. This time technical inefficiency calculated for the nonhedonic frontier specification amounts to 0.436, or 43.6%, a much more reasonable figure than before. It appears that by giving the analysis an improved theoretical foundation results may be more generally reliable; and the overall level of technical inefficiency is only one third of that suggested by the earlier results.

Using Spearman's rank correlation coefficient once again, pairs of rankings may be assessed. Findings are as follows. For rankings 3 and 4 ie nonhedonic and hedonic specifications r = 0.7525 indicating fairly strong positive correlation. The output variable clearly lies behind this conclusion. For rankings 3 and 5, corresponding to the OLS and frontier estimates, r = 0.9996 indicating very strong correlation, and suggesting that OLS residual rankings do indeed mirror those of frontier estimation.

Overall the models presented above, although limited, do not appear any less satisfactory than those of Knapp (1978). Furthermore the latter models are more theoretically sound. But throughout it has become clear that the hedonic specifications taking into account the physical characteristics of operations are the most appropriate and the most plausible.

One final piece of analysis was undertaken. With all ten RWA's represented in the sample an attempt was made to assess whether or not any one particular authority enjoyed consistently lower rankings (ie greater efficiency) for all estimated models. Tables 5.10 and 5.11 below give the mean and standard deviations of rankings for each of the five models reported by Water Authority area. A lower mean represents a higher average ranking on all models for works in the area. Standard deviations represent dispersion of results; and may proxy the potential for making efficiency improvements. High standard deviations would indicate greater potential for making efficiency improvements by works within one authority's area. R1 to R5 correspond to tables of ranks in the appendix and hence the five models reported.

Table 5.10.

Mean Rankings by Water Authority Area.

AREA	TABLE				
	R1	R2	R3	R4	R5
Anglian	67.6	71.1	64.7	58.5	64.5
Northumbrian	77.8	81.7	63.1	78.0	63.3
North West	65.3	58.6	83.3	61.4	83.3
Severn Trent	61.7	68.6	72.4	71.1	72.1
Southern	75.3	75.9	66.3	74.6	65.5
South West	86.9	72.4	58.9	74.9	58.6
Thames	78.2	78.3	91.5	93.5	90.8
Welsh	89.0	89.9	78.6	83.2	78.1
Wessex	62.3	60.8	46.7	54.4	46.8
Yorkshire	72.6	74.1	72.9	76.3	74.7

Table 5.11.

Standard Deviation of Rankings by Water Authority Area.

AREA	TABLE				
	R1	R2	R3	R4	R5
Anglian	41.3	44.8	35.4	33.3	35.4
Northumbrian	48.3	50.5	40.5	46.3	40.5
North West	29.1	29.2	39.9	38.6	40.0
Severn Trent	37.3	36.5	44.7	32.3	44.8
Southern	40.7	44.9	43.3	45.6	42.7
South West	35.7	33.7	31.4	40.9	31.3
Thames	39.4	40.9	32.8	34.5	32.7
Welsh	49.2	47.6	33.6	45.3	33.6
Wessex	42.0	37.0	20.2	34.8	20.1
Yorkshire	44.7	41.1	48.6	45.7	48.9

Overall, although the differences are not great, the Wessex Region has the lowest mean rank most consistently, followed by Anglian and Severn Trent. Thames has the highest mean rank followed by Wales and Yorkshire. In noting these results it should be remembered that only the largest treatment works of each region are included, and therefore a scale effect may be picked up in the above tables. However, on reexamining the data, the scale of works for Thames and Wessex in the sample do not appear to be radically different. Overall, the results do give some indication of relative efficiency region by region on the same lines as that undertaken in the 'banding' exercise of Chapter 4.

7. Conclusions.

So what are we to conclude from these rather uneven results? Are we able to say anything with any degree of confidence?

The starting point must be the rather disappointing results from the point of view of orthodox economic theory. Linear cost models which draw little on neoclassical production theory appear to outperform their carefully specified counterparts according to most testing criteria. But the question must be asked as to whether one should be overconcerned with the theoretical niceties in constructing a tractable system of comparative efficiency measurement. A first best, theoretically watertight method is probably unattainable given the limitations of technique and data. A second best alternative is probably all that can be achieved: and, more significantly, all that is required by a regulator. In this light, the approach presented above may be regarded as a good 'first approximation' to the solution. After all, few would argue that industrial production takes place in a Cobb Douglas world. Empirical observation must shape our theory, not the other way around. No excuses need be made for functional forms which are convenient for the purposes of algebraic manipulation but lacking in other respects.

One of the other difficulties in the study is the specification of the output measure. Much empirical work is conducted at a higher level of aggregation so the issue of output quality does not arise. This chapter has taken a quite different approach in continuing to work at the micro level. Aggregation is rejected; and its rejection causes many complications. But ultimately it must be more illuminating to work with hedonic variables than to assume them away.

More positively it was found that price factors are not the crucial element in determining cost functions. They are swamped by hedonic variables which represent the conditions under which firms operate. This effect may be amplified by the particular dataset used in this study. As mentioned above, price variables have little or no variation across the cross section. However, it remains generally the case that the heterogeneous circumstances under which firms operate determine the cost profile. For sewage treatment and disposal, different physical terrain, population density and industrial activities influence methods of treatment and disposal. The real challenge for a regulator is to understand these conditions and make allowance for them in any analysis. For England and Wales, the work on 'explanatory factors' by Ofwat and the water and sewerage companies indicates that they are fully appraised of this. Any comparative efficiency measurement must take full account of the different circumstances faced by each operator.

To be aware to the importance of heterogeneity is the first important step. To analyze it for one sector of the industry is the second. But it remains to be seen if the problem is more exaggerated for sewage treatment and disposal than for water. From the evidence presented above it appears that it is. Sewage is more heterogeneous than water in quality terms as it comes into a treatment works and as it leaves. Therefore, hedonic variables are more likely to have a greater influence on the cost function. But with greater variation, the difficulties of constructing a system of comparative efficiency measurement are increased. The more heterogeneous the circumstances, the more they depart from Shleifer's (1985) ideal conditions and the more difficult is the implementation of yardstick competition. A regulator would therefore be advised to begin with water and move on to sewage.

Given all the reservations over the results, they do nonetheless indicate that large differences in technical efficiency exist between operating units in the industry. The high figures suggest that in the year of the study there was great scope for improvements in efficiency and cost savings.

Comparing the results, briefly, with those of Chapter 4, many parallels may be drawn. Both pieces of work have demonstrated that a method of comparative efficiency measurement using econometric techniques may be operated. Both studies have indicated that price terms may not be the key determinant of the various cost functions. Theoretically sound functional forms proved very difficult to maintain and Cobb Douglas models were used throughout. But technically, the sewerage study had the edge on the water study in that cardinal measures of inefficiency may be derived from the cross sectional data. This is not the case with fixed effects models employing panel data; although as has been noted this does not invalidate the use of the techniques in an regulatory solution based on a system of yardstick competition. The weaker ordinal rankings are sufficient for the purpose.

Finally it appears to be the case that both the sewerage and water operators had no clear basis of judging the efficiency of their operations. Considerable ignorance surrounded their work; an ignorance that the results of econometric cost function estimation may do something to dispel.

Thus using plant level cross sectional sewage treatment and disposal data, this chapter has demonstrated how a tractable means of comparative efficiency measurement for yardstick competition may be worked. Ordinal rankings based on residuals contain sufficient information for the construction of comparators and through the use of Spearman's correlation coefficient some of these have been shown to be robust.

Appendix I.

CIPFA Sewage Treatment and Disposal Statistics 1979-80:

Variables Reported.

Water Authority / Division / Works.
Date of commencement of operation or any major reconstruction.
Population of area draining to the works.
Method of purification.
Dry weather flow (cubic metres per day).
Trade effluent (cubic metres per day).
Total Sewage Flow (cubic metres per day).
Proportion of dry weather flow which is treated (%).
Average strength of influent (mg/litre)
- 5 days Biochemical Oxygen Demand (BOD) at 20°C
- Chemical Oxygen Demand (COD)
- Suspended solids (SS)

Approved river standard (mg/litre)
- 5 days BOD at 20°C
- COD
- Suspended solids

Standard of purification actually achieved (mg/litre)
- 5 days BOC at 20°C
- COD
- Suspended solids

Works charges (costs per cubic metre DWF)
- Sewage purification (subdivided by treatment method)
- Sludge disposal (subdivided by disposal method)
- Other direct works charges
- Gross works costs

Appendix II.

CIPFA Sewage Treatment and Disposal Statistics 1979-80:

Method of Purification.	Dummy Variable
Biological Filtration:	
- Single Filtration	DA
- Other	DB
Activated Sludge:	
- Diffused Air	DC
- Mechanical	DD
- Pure Oxygen Plant	DE
Tertiary Treatment:	
- Land	DF
- Micro Strainers	DG
- Sand Filters	DH
Sludge Digestion:	
- Heated	DJ
- Cold	DK
Mechanical Dewatering:	
- Vacuum Filtration	DL
- Pressing or Other Methods	DM

Appendix III.

Other Variables: Sources.

Rainfall:
- Annual Rainfall by Water Authority Area 1980 (mm). Water Services Association, 'Waterfacts 1986' Table 2A p6.

Prices:
- Price of Labour (PL) Average hourly earnings (pence) manual men in other energy and water supply for 1980 (SIC 15-17). New Earnings Survey Part E, 1990.
- Price of Electricity (PE) Average net selling value per KwHr (pence) for waterworks including gasworks, drainage and sewage pumping stations (1980). Digest of UK Energy Statistics 1982 Table 61 pp92-93.
- Price of Rates (PR) Average non-domestic rate poundage (pence) for English Authorities 1979/80. Local Government Financial Statistics England and Wales 1980/1 p36 Table 21.
- Retail Prices Index (PP) November 1980. Water Services Association 'Waterfacts 1990' p12.

Appendix IV.

Tables of residuals for individual works under the various modelling assumptions.

R1, R2, R3, R4, R5 represent residuals.

ID represents Local Water Authority area:

1 = Anglian
2 = Northumbrian
3 = North West
4 = Severn Trent
5 = Southern
6 = South West
7 = Thames
8 = Welsh
9 = Wessex
10 = Yorkshire

Table R1.

WORKS	ID	R1	RANK
Little Marlow	7	-3.0504	1
Otley	10	-1.9763	2
Miskin	8	-1.6365	3
Tiverton-Holywell	6	-1.5841	4
Bishop Auckland	2	-1.5083	5
Stoke Bardolph	4	-1.4571	6
Hayden	4	-1.3925	7
Gravesend-Denton	5	-1.3395	8
Trowbridge	9	-1.3258	9
Eccles	3	-1.1897	10
Bridgewater	9	-1.1866	11
Peterborough-Fengate	1	-1.1589	12
Cynon Valley	8	-1.0871	13
Norwich-Whitlingham	1	-1.0571	14
Cambridge	1	-1.0467	15
Derby	4	-1.0417	16
Brighouse	10	-0.9815	17
Blackburn	3	-0.9523	18
Finedon	1	-0.9393	19
Yaddlethorpe	4	-0.9311	20
Wellington-Tone	9	-0.9077	21
Sittingbourne	5	-0.9047	22
Keighley-Marley	10	-0.8745	23
Macclesfield	3	-0.8189	24
Barnhurst	4	-0.8167	25
Consett	2	-0.7997	26
Loughborough	4	-0.7443	27
Bristol-Avonmouth	9	-0.7273	28
Chesterfield	10	-0.7189	29

Medway-Motney Hill	5	-0.6616	30
Sutton-Byram Park	10	-0.6537	31
Warrington	3	-0.6222	32
Blackbirds	7	-0.6059	33
Chertsey	7	-0.6032	34
Fareham-Salterns Lane	5	-0.5932	35
Freehold	4	-0.5744	36
Barmston Lane	2	-0.5683	37
Barnsley-Lund Wood	10	-0.568	38
Rotherham-Aldwarke	10	-0.5549	39
Bury	3	-0.548	40
Liverpool-North	3	-0.538	41
Tonbridge	5	-0.5255	42
Rushmoor	4	-0.5252	43
Clay Mills	4	-0.5248	44
Poole	9	-0.5157	45
Huddersfield	10	-0.4993	46
Southend-Prittlewell	1	-0.4813	47
Bradford-North Brierley	10	-0.4805	48
High Wycombe	7	-0.4668	49
Salisbury	9	-0.4612	50
Lincoln-Canwick	1	-0.4524	51
Carlisle	3	-0.4289	52
Basildon-Nevendon	1	-0.4144	53
Northampton-Great Billing	1	-0.4018	54
Canterbury	5	-0.3887	55
Southport	3	-0.3872	56
Dukinfield	3	-0.3309	57
Maple Lodge	7	-0.2820	58
Owlwood	10	-0.2758	59
Darlington-Stressholme	2	-0.2671	60
St Austell-Menagwins	6	-0.2497	61
Kidderminster-Oldington	4	-0.2243	62
Bolton	3	-0.2174	63
Basingstoke	7	-0.1804	64
Birtley	2	-0.1755	65
Penybont	8	-0.1672	66
Salford	3	-0.1594	67
Netheridge	4	-0.1400	68
Wawlip	4	-0.1392	69
Corby	1	-0.1229	70
Rochdale	3	-0.1217	71
Minworth	4	-0.1147	72
Bath Saltford	9	-0.1051	73
Stockport	3	-0.0980	74
Rossendale	3	-0.0969	75
Worcester	4	-0.0934	76
Havant-Budds Farm	5	-0.0489	77
Oldham	3	-0.0319	78
Thornham	5	-0.0131	79
Hoscar	3	-0.0071	80
Southampton-Woolston	5	-0.0023	81
Ashford	5	0.0041	82
Brockhurst	4	0.0062	83

Ponthir	8	0.0090	84
Davyhulme	3	0.0368	85
Burnley	3	0.0539	86
Strongford	4	0.1044	87
Brancote	4	0.1159	88
Crewe	3	0.1159	89
Exeter-Countess Wear	6	0.1378	90
York-Naburn	10	0.1613	91
Cirencester-Shorncote	7	0.1757	92
Bournemouth-Holdenhurst	9	0.1868	93
Sheffield-Blackburn Meadows	10	0.1871	94
Reading-Manor Farm	7	0.2030	95
Plymouth-Camels Head	6	0.2141	96
Cramlington	2	0.2214	97
Roundhill	4	0.2340	98
Colchester-Haven	1	0.2412	99
Truro-Newham	6	0.2668	100
Chester-Sealand Road	8	0.2741	101
Preston-Clifton Marsh	3	0.3054	102
Chelmsford-Brookend	1	0.3086	103
Thurrock-Marsh Farm	1	0.3145	104
Guildford	7	0.3180	105
Coleshill	4	0.3276	106
Southampton-Millbrook	5	0.3332	107
Plymouth-Ernesettle	6	0.3500	108
Leeds-Knostrop	10	0.3571	109
Dewsbury-Mitchell Laithes	10	0.3720	110
Doncaster-Sandall	10	0.3978	111
Runcorn	3	0.5063	112
Kingston-Seymour	9	0.5134	113
Bedford-Summerhouse Hill	1	0.5577	114
Bradford-Esholt	10	0.5715	115
Taunton-Ham	9	0.7750	116
Barnstaple-Ashford	6	0.8547	117
Slough	7	0.8841	118
Plymouth-Marsh Mills	6	0.9051	119
Luton-East Hyde	7	0.9151	120
Harlow-Rye Meads	7	0.9663	121
Maidstone-Aylesford	5	0.9735	122
Ray Hall	4	1.0422	123
St Helens	3	1.1581	124
Eastleigh-Chickenhall Lane	5	1.1687	125
Christchurch	9	1.2017	126
Swindon-Rodbourne	7	1.2246	127
Ipswich-Cliff Quay	1	1.2743	128
Hereford	8	1.3277	129
Durham-Barkers Haugh	2	1.5524	130
Wellingborough-Broadholme	1	1.6188	131
Southampton-Portswood	5	1.6751	132
Fullerton-Andover	5	1.6936	133
Gowerton	8	1.7728	134
Wrexham-Five Fords	8	1.8220	135
Nash	8	1.8367	136
Wakefield-Calder Vale	10	2.1168	137

Morley	10	2.2725	138
Sedgeletch	2	2.6088	139
Leek	4	3.2079	140
Aycliffe	2	3.2520	141
Halifax-North Dean	10	3.2817	142

Table R2.

WORKS	ID	R2	RANK
Little Marlow	7	0.1141	1
Peterborough-Fengate	1	0.1273	2
Eccles	3	0.1578	3
Bishop Auckland	2	0.1829	4
Tiverton-Holywell	6	0.1967	5
Cynon Valley	8	0.2245	6
Finedon	1	0.2358	7
Stoke Bardolph	4	0.2372	8
Brighouse	10	0.2472	9
Gravesend-Denton	5	0.2490	10
Hayden	4	0.2518	11
Bridgewater	9	0.2718	12
Blackburn	3	0.2720	13
Bristol-Avonmouth	9	0.2880	14
Norwich-Whitlingham	1	0.2929	15
Keighley-Marley	10	0.2970	16
Medway-Motney Hill	5	0.3386	17
Sittingbourne	5	0.3414	18
Cambridge	1	0.3447	19
Maple Lodge	7	0.3506	20
Consett	2	0.3548	21
Yaddlethorpe	4	0.3564	22
Miskin	8	0.3693	23
Otley	10	0.3916	24
Blackbirds	7	0.4212	25
Southend-Prittlewell	1	0.4372	26
Tonbridge	5	0.4492	27
Warrington	3	0.4572	28
Salford	3	0.4665	29
Sutton-Byram Park	10	0.4795	30
Fareham-Salterns Lane	5	0.4878	31
Minworth	4	0.5009	32
Rushmoor	4	0.5022	33
Carlisle	3	0.5178	34
Macclesfield	3	0.5228	35
Wellington-Tone	9	0.5304	36
Barnsley-Lund Wood	10	0.5413	37
Rotherham-Aldwarke	10	0.5470	38
Strongford	4	0.5536	39
Southport	3	0.5600	40
Barmston Lane	2	0.5656	41
Liverpool-North	3	0.5967	42
Salisbury	9	0.6119	43
Trowbridge	9	0.6154	44
Netheridge	4	0.6514	45

Poole	9	0.6758	46
Chesterfield	10	0.7084	47
Darlington-Stressholme	2	0.7159	48
Oldham	3	0.7345	49
Rossendale	3	0.7372	50
Thornham	5	0.7412	51
Northampton-Great Billing	1	0.7432	52
Bath Saltford	9	0.7495	53
Bolton	3	0.7524	54
Plymouth-Ernesettle	6	0.7720	55
High Wycombe	7	0.7926	56
Owlwood	10	0.8086	57
Exeter-Countess Wear	6	0.8103	58
Worcester	4	0.8154	59
Bury	3	0.8177	60
Freehold	4	0.8199	61
Penybont	8	0.8342	62
Barnhurst	4	0.8392	63
Preston-Clifton Marsh	3	0.9110	64
Kidderminster-Oldington	4	0.9128	65
Chertsey	7	0.9474	66
Coleshill	4	0.9503	67
Bradford-North Brierley	10	0.9825	68
Canterbury	5	1.0085	69
Rochdale	3	1.0110	70
St Austell-Menagwins	6	1.0476	71
Dukinfield	3	1.0527	72
Basingstoke	7	1.0634	73
Crewe	3	1.0782	74
Truro-Newham	6	1.1026	75
York-Naburn	10	1.1152	76
Derby	4	1.1315	77
Bournemouth-Holdenhurst	9	1.1363	78
Huddersfield	10	1.1420	79
Ponthir	8	1.1467	80
Davyhulme	3	1.1548	81
Barnstaple-Ashford	6	1.1588	82
Corby	1	1.1601	83
Hoscar	3	1.1633	84
Wawlip	4	1.1740	85
Cirencester-Shorncote	7	1.1776	86
Stockport	3	1.1905	87
Colchester-Haven	1	1.2162	88
Clay Mills	4	1.2451	89
Lincoln-Canwick	1	1.2489	90
Southampton-Millbrook	5	1.2568	91
Havant-Budds Farm	5	1.2735	92
Doncaster-Sandall	10	1.2974	93
Brancote	4	1.2988	94
Birtley	2	1.3058	95
Basildon-Nevendon	1	1.3455	96
Leeds-Knostrop	10	1.3792	97
Burnley	3	1.3899	98
Chelmsford-Brookend	1	1.4063	99

Ashford	5	1.4081	100
Harlow-Rye Meads	7	1.4140	101
Bradford-Esholt	10	1.4619	102
Chester-Sealand Road	8	1.4653	103
St Helens	3	1.5050	104
Reading-Manor Farm	7	1.5159	105
Kingston-Seymour	9	1.5258	106
Loughborough	4	1.5576	107
Brockhurst	4	1.5797	108
Guildford	7	1.5851	109
Sheffield-Blackburn Meadows	10	1.6114	110
Roundhill	4	1.6601	111
Bedford-Summerhouse Hill	1	1.7233	112
Plymouth-Camels Head	6	1.7283	113
Ipswich-Cliff Quay	1	1.8042	114
Dewsbury-Mitchell Laithes	10	1.8141	115
Taunton-Ham	9	1.8954	116
Cramlington	2	1.9315	117
Southampton-Woolston	5	1.9337	118
Runcorn	3	2.0353	119
Plymouth-Marsh Mills	6	2.0510	120
Christchurch	9	2.1962	121
Luton-East Hyde	7	2.2069	122
Ray Hall	4	2.4353	123
Hereford	8	2.4464	124
Eastleigh-Chickenhall Lane	5	2.5199	125
Slough	7	2.5376	126
Maidstone-Aylesford	5	2.5717	127
Swindon-Rodbourne	7	2.6750	128
Durham-Barkers Haugh	2	2.7338	129
Thurrock-Marsh Farm	1	2.7566	130
Southampton-Portswood	5	2.8279	131
Fullerton-Andover	5	2.9713	132
Wellingborough-Broadholme	1	3.0063	133
Wakefield-Calder Vale	10	3.1125	134
Morley	10	3.2876	135
Wrexham-Five Fords	8	3.3360	136
Gowerton	8	3.5073	137
Nash	8	3.6660	138
Sedgeletch	2	3.9612	139
Halifax-North Dean	10	4.5835	140
Aycliffe	2	4.6788	141
Leek	4	6.3659	142

Table R3.

WORKS	ID	R3	RANK
Sittingbourne	5	-1.2240	1
Eccles	3	-1.1126	2
Keighley-Marley	10	-1.0799	3
Gravesend-Denton	5	-0.9062	4
Tonbridge	5	-0.8958	5
Salisbury	9	-0.8258	6

Bishop Auckland	2	-0.8134	7
Otley	10	-0.7595	8
Brancote	4	-0.7536	9
Finedon	1	-0.7241	10
Consett	2	-0.7170	11
Sutton-Byram Park	10	-0.7084	12
Yaddlethorpe	4	-0.6874	13
Barmston Lane	2	-0.6555	14
Blackburn	3	-0.6511	15
Peterborough-Fengate	1	-0.6428	16
Hayden	4	-0.6132	17
Netheridge	4	-0.5875	18
Tiverton-Holywell	6	-0.5397	19
Owlwood	10	-0.5300	20
Penybont	8	-0.5188	21
Salford	3	-0.5122	22
Rushmoor	4	-0.4955	23
Thornham	5	-0.4808	24
Truro-Newham	6	-0.4641	25
Trowbridge	9	-0.4448	26
Chesterfield	10	-0.4406	27
Colchester-Haven	1	-0.4083	28
Strongford	4	-0.4027	29
Brighouse	10	-0.4013	30
Warrington	3	-0.3855	31
Northampton-Great Billing	1	-0.3573	32
Havant-Budds Farm	5	-0.3403	33
Bristol-Avonmouth	9	-0.3354	34
Freehold	4	-0.3332	35
St Austell-Menagwins	6	-0.3274	36
Barnsley-Lund Wood	10	-0.3245	37
Little Marlow	7	-0.3036	38
Cambridge	1	-0.2971	39
Southend-Prittlewell	1	-0.2951	40
Wellington-Tone	9	-0.2890	41
Bournemouth-Holdenhurst	9	-0.2770	42
Rotherham-Aldwarke	10	-0.2763	43
Chertsey	7	-0.2635	44
Fareham-Salterns Lane	5	-0.2405	45
Southport	3	-0.2389	46
Poole	9	-0.2316	47
Bridgewater	9	-0.2253	48
Carlisle	3	-0.2204	49
Barnstaple-Ashford	6	-0.2167	50
Clay Mills	4	-0.2108	51
Corby	1	-0.2050	52
Blackbirds	7	-0.1778	53
Kingston-Seymour	9	-0.1585	54
Cynon Valley	8	-0.1564	55
Ponthir	8	-0.1452	56
Wrexham-Five Fords	8	-0.1408	57
Kidderminster-Oldington	4	-0.1371	58
Roundhill	4	-0.1337	59
Morley	10	-0.1199	60

Taunton-Ham	9	-0.1104	61
Liverpool-North	3	-0.0914	62
Cirencester-Shorncote	7	-0.0676	63
Basingstoke	7	-0.0647	64
Plymouth-Marsh Mills	6	-0.0583	65
Plymouth-Ernesettle	6	-0.0534	66
Ashford	5	-0.0361	67
Medway-Motney Hill	5	-0.0277	68
Worcester	4	-0.0091	69
Durham-Barkers Haugh	2	-0.0063	70
Chester-Sealand Road	8	-0.0057	71
Darlington-Stressholme	2	0.0017	72
Bedford-Summerhouse Hill	1	0.0026	73
Norwich-Whitlingham	1	0.0154	74
Bath Saltford	9	0.0172	75
Dewsbury-Mitchell Laithes	10	0.0241	76
Dukinfield	3	0.0482	77
Barnhurst	4	0.0694	78
Chelmsford-Brookend	1	0.0761	79
Christchurch	9	0.0858	80
Macclesfield	3	0.0900	81
Preston-Clifton Marsh	3	0.1246	82
Doncaster-Sandall	10	0.1265	83
Birtley	2	0.1268	84
Aycliffe	2	0.1447	85
Stoke Bardolph	4	0.1505	86
Southampton-Woolston	5	0.1535	87
Lincoln-Canwick	1	0.1548	88
Bolton	3	0.1553	89
Bradford-Esholt	10	0.1612	90
Hereford	8	0.1654	91
Southampton-Millbrook	5	0.1744	92
Maidstone-Aylesford	5	0.1814	93
Basildon-Nevendon	1	0.1818	94
Exeter-Countess Wear	6	0.1882	95
Cramlington	2	0.1982	96
Crewe	3	0.2033	97
Burnley	3	0.2076	98
York-Naburn	10	0.2193	99
Stockport	3	0.2245	100
Guildford	7	0.2280	101
Reading-Manor Farm	7	0.2315	102
Hoscar	3	0.2408	103
Ray Hall	4	0.2455	104
Ipswich-Cliff Quay	1	0.2858	105
Brockhurst	4	0.2996	106
Loughborough	4	0.3042	107
Miskin	8	0.3160	108
Harlow-Rye Meads	7	0.3566	109
High Wycombe	7	0.3674	110
Bury	3	0.3733	111
Coleshill	4	0.3817	112
Wellingborough-Broadholme	1	0.3823	113
Southampton-Portswood	5	0.3852	114

Plymouth-Camels Head	6	0.3935	115
Canterbury	5	0.4125	116
Gowerton	8	0.4318	117
Oldham	3	0.4503	118
Bradford-North Brierley	10	0.4569	119
Rossendale	3	0.4702	120
Maple Lodge	7	0.4774	121
Eastleigh-Chickenhall Lane	5	0.4806	122
Fullerton-Andover	5	0.4904	123
Runcorn	3	0.5024	124
Slough	7	0.5495	125
Wawlip	4	0.5585	126
Thurrock-Marsh Farm	1	0.5599	127
Swindon-Rodbourne	7	0.5835	128
Sedgeletch	2	0.5969	129
Wakefield-Calder Vale	10	0.6559	130
Nash	8	0.6572	131
Luton-East Hyde	7	0.6741	132
Rochdale	3	0.6998	133
Sheffield-Blackburn Meadows	10	0.7028	134
Davyhulme	3	0.7757	135
Huddersfield	10	0.7878	136
Leeds-Knostrop	10	0.8096	137
St Helens	3	0.8133	138
Derby	4	0.9895	139
Leek	4	1.3924	140
Halifax-North Dean	10	1.4138	141
Minworth	4	2.0343	142

Table R4

WORKS	ID	R4	RANK
Eccles	3	-1.0162	1
Keighley-Marley	10	-0.7904	2
Warrington	3	-0.7445	3
Blackburn	3	-0.7229	4
Little Marlow	7	-0.6854	5
Gravesend-Denton	5	-0.6657	6
Finedon	1	-0.6317	7
Bristol-Avonmouth	9	-0.6231	8
Brighouse	10	-0.6217	9
Sittingbourne	5	-0.6089	10
Cynon Valley	8	-0.5371	11
Medway-Motney Hill	5	-0.5163	12
Netheridge	4	-0.5008	13
Plymouth-Ernesettle	6	-0.4860	14
Salford	3	-0.4689	15
Barnsley-Lund Wood	10	-0.4514	16
Southend-Prittlewell	1	-0.4498	17
Hayden	4	-0.4368	18
Fareham-Salterns Lane	5	-0.4348	19
Peterborough-Fengate	1	-0.4327	20

Bridgewater	9	-0.4243	21
Bishop Auckland	2	-0.4033	22
Trowbridge	9	-0.4013	23
Tonbridge	5	-0.3936	24
Rotherham-Aldwarke	10	-0.3840	25
Preston-Clifton Marsh	3	-0.3822	26
Barmston Lane	2	-0.3760	27
Stoke Bardolph	4	-0.3713	28
Carlisle	3	-0.3693	29
Sutton-Byram Park	10	-0.3692	30
Consett	2	-0.3604	31
Salisbury	9	-0.3451	32
Yaddlethorpe	4	-0.3308	33
Otley	10	-0.3240	34
Poole	9	-0.3177	35
Miskin	8	-0.3156	36
Tiverton-Holywell	6	-0.2794	37
Liverpool-North	3	-0.2600	38
Cambridge	1	-0.2567	39
Barnstaple-Ashford	6	-0.2188	40
Northampton-Great Billing	1	-0.2073	41
Macclesfield	3	-0.1950	42
Darlington-Stressholme	2	-0.1902	43
Southport	3	-0.1810	44
Corby	1	-0.1677	45
Chesterfield	10	-0.1461	46
Rushmoor	4	-0.1401	47
Brancote	4	-0.1176	48
Chertsey	7	-0.1130	49
Penybont	8	-0.1041	50
Wellington-Tone	9	-0.0989	51
Norwich-Whitlingham	1	-0.0984	52
Ponthir	8	-0.0895	53
St Austell-Menagwins	6	-0.0794	54
Clay Mills	4	-0.0594	55
Colchester-Haven	1	-0.0590	56
Bath Saltford	9	-0.0570	57
Dukinfield	3	-0.0408	58
Lincoln-Canwick	1	-0.0363	59
Ipswich-Cliff Quay	1	-0.0288	60
Bournemouth-Holdenhurst	9	-0.0282	61
Chelmsford-Brookend	1	-0.0260	62
Kidderminster-Oldington	4	-0.0254	63
Barnhurst	4	-0.0187	64
York-Naburn	10	0.0045	65
Stockport	3	0.0112	66
Burnley	3	0.0150	67
Freehold	4	0.0157	68
Bolton	3	0.0177	69
Havant-Budds Farm	5	0.0185	70
Strongford	4	0.0247	71
Rossendale	3	0.0403	72
Oldham	3	0.0454	73
Roundhill	4	0.0464	74

Basingstoke	7	0.0547	75
Bradford-North Brierley	10	0.0561	76
Crewe	3	0.0683	77
Doncaster-Sandall	10	0.0702	78
Birtley	2	0.0739	79
Chester-Sealand Road	8	0.0866	80
Minworth	4	0.0875	81
Maple Lodge	7	0.0895	82
Blackbirds	7	0.0944	83
Kingston-Seymour	9	0.0987	84
Ashford	5	0.1175	85
Bedford-Summerhouse Hill	1	0.1176	86
Worcester	4	0.1195	87
Derby	4	0.1238	88
Thornham	5	0.1340	89
Basildon-Nevendon	1	0.1473	90
Coleshill	4	0.1528	91
Southampton-Millbrook	5	0.1581	92
Bury	3	0.1602	93
Wawlip	4	0.1683	94
Slough	7	0.1700	95
Cramlington	2	0.1822	96
Owlwood	10	0.1860	97
Huddersfield	10	0.1942	98
Taunton-Ham	9	0.2056	99
Hoscar	3	0.2147	100
Brockhurst	4	0.2169	101
High Wycombe	7	0.2192	102
Southampton-Woolston	5	0.2200	103
Truro-Newham	6	0.2242	104
Plymouth-Marsh Mills	6	0.2324	105
Reading-Manor Farm	7	0.2367	106
Rochdale	3	0.2498	107
Dewsbury-Mitchell Laithes	10	0.2590	108
Runcorn	3	0.2711	109
Exeter-Countess Wear	6	0.2713	110
Loughborough	4	0.2733	111
Bradford-Esholt	10	0.2912	112
Maidstone-Aylesford	5	0.2941	113
Thurrock-Marsh Farm	1	0.3199	114
Wrexham-Five Fords	8	0.3302	115
Leeds-Knostrop	10	0.3322	116
Guildford	7	0.3324	117
Harlow-Rye Meads	7	0.3333	118
Davyhulme	3	0.3485	119
Cirencester-Shorncote	7	0.3602	120
Eastleigh-Chickenhall Lane	5	0.3709	121
Ray Hall	4	0.3734	122
Southampton-Portswood	5	0.3856	123
Canterbury	5	0.3910	124
Durham-Barkers Haugh	2	0.3988	125
Morley	10	0.4146	126
Christchurch	9	0.4422	127
Fullerton-Andover	5	0.4679	128

Wellingborough-Broadholme	1	0.4753	129
Hereford	8	0.4865	130
Luton-East Hyde	7	0.4894	131
Sheffield-Blackburn Meadows	10	0.4996	132
Swindon-Rodbourne	7	0.5245	133
Gowerton	8	0.5314	134
Plymouth-Camels Head	6	0.5339	135
Leek	4	0.5526	136
Wakefield-Calder Vale	10	0.6005	137
Aycliffe	2	0.6525	138
St Helens	3	0.6581	139
Nash	8	0.6765	140
Sedgeletch	2	0.8158	141
Halifax-North Dean	10	1.0881	142

Table R5.

WORKS	ID	R5	RANK
Sittingbourne	5	0.1276	1
Eccles	3	0.1395	2
Keighley-Marley	10	0.1457	3
Gravesend-Denton	5	0.1619	4
Tonbridge	5	0.1634	5
Salisbury	9	0.1747	6
Bishop Auckland	2	0.1769	7
Brancote	4	0.1849	8
Otley	10	0.1892	9
Finedon	1	0.1901	10
Consett	2	0.1923	11
Yaddlethorpe	4	0.1959	12
Sutton-Byram Park	10	0.1979	13
Barmston Lane	2	0.2033	14
Blackburn	3	0.2041	15
Peterborough-Fengate	1	0.2046	16
Hayden	4	0.2095	17
Netheridge	4	0.2145	18
Tiverton-Holywell	6	0.2252	19
Penybont	8	0.2296	20
Salford	3	0.2321	21
Owlwood	10	0.2333	22
Rushmoor	4	0.2337	23
Thornham	5	0.2358	24
Truro-Newham	6	0.2422	25
Trowbridge	9	0.2470	26
Chesterfield	10	0.2548	27
Colchester-Haven	1	0.2555	28
Strongford	4	0.2565	29
Warrington	3	0.2626	30
Brighouse	10	0.2646	31
Northampton-Great Billing	1	0.2690	32
Havant-Budds Farm	5	0.2713	33
Freehold	4	0.2741	34
Bristol-Avonmouth	9	0.2759	35

St Austell-Menagwins	6	0.2771	36
Little Marlow	7	0.2811	37
Cambridge	1	0.2856	38
Barnsley-Lund Wood	10	0.2860	39
Southend-Prittlewell	1	0.2860	40
Wellington-Tone	9	0.2879	41
Bournemouth-Holdenhurst	9	0.2923	42
Chertsey	7	0.2927	43
Fareham-Salterns Lane	5	0.2995	44
Rotherham-Aldwarke	10	0.3004	45
Southport	3	0.3043	46
Poole	9	0.3060	47
Bridgewater	9	0.3073	48
Barnstaple-Ashford	6	0.3100	49
Carlisle	3	0.3101	50
Clay Mills	4	0.3108	51
Corby	1	0.3134	52
Blackbirds	7	0.3199	53
Cynon Valley	8	0.3297	54
Kingston-Seymour	9	0.3297	55
Ponthir	8	0.3338	56
Kidderminster-Oldington	4	0.3353	57
Wrexham-Five Fords	8	0.3356	58
Roundhill	4	0.3366	59
Taunton-Ham	9	0.3470	60
Morley	10	0.3534	61
Liverpool-North	3	0.3549	62
Cirencester-Shorncote	7	0.3580	63
Basingstoke	7	0.3598	64
Plymouth-Marsh Mills	6	0.3664	65
Plymouth-Ernesettle	6	0.3674	66
Ashford	5	0.3706	67
Medway-Motney Hill	5	0.3740	68
Worcester	4	0.3834	69
Chester-Sealand Road	8	0.3864	70
Durham-Barkers Haugh	2	0.3882	71
Bedford-Summerhouse Hill	1	0.3899	72
Darlington-Stressholme	2	0.3917	73
Norwich-Whitlingham	1	0.3953	74
Bath Saltford	9	0.3966	75
Dukinfield	3	0.4105	76
Dewsbury-Mitchell Laithes	10	0.4117	77
Barnhurst	4	0.4167	78
Chelmsford-Brookend	1	0.4210	79
Christchurch	9	0.4260	80
Macclesfield	3	0.4288	81
Preston-Clifton Marsh	3	0.4449	82
Birtley	2	0.4459	83
Southampton-Woolston	5	0.4519	84
Stoke Bardolph	4	0.4537	85
Aycliffe	2	0.4553	86
Lincoln-Canwick	1	0.4567	87
Doncaster-Sandall	10	0.4576	88
Bolton	3	0.4599	89

Hereford	8	0.4623	90
Southampton-Millbrook	5	0.4623	91
Maidstone-Aylesford	5	0.4656	92
Basildon-Nevendon	1	0.4698	93
Exeter-Countess Wear	6	0.4742	94
Bradford-Esholt	10	0.4753	95
Cramlington	2	0.4800	96
Crewe	3	0.4824	97
Burnley	3	0.4845	98
Guildford	7	0.4884	99
Reading-Manor Farm	7	0.4906	100
Stockport	3	0.4935	101
Ray Hall	4	0.4998	102
Hoscar	3	0.5019	103
York-Naburn	10	0.5033	104
Ipswich-Cliff Quay	1	0.5222	105
Brockhurst	4	0.5278	106
Loughborough	4	0.5298	107
Miskin	8	0.5367	108
Harlow-Rye Meads	7	0.5569	109
High Wycombe	7	0.5617	110
Southampton-Portswood	5	0.5715	111
Coleshill	4	0.5727	112
Bury	3	0.5728	113
Wellingborough-Broadholme	1	0.5748	114
Plymouth-Camels Head	6	0.5821	115
Canterbury	5	0.5866	116
Gowerton	8	0.6023	117
Oldham	3	0.6165	118
Maple Lodge	7	0.6256	119
Eastleigh-Chickenhall Lane	5	0.6261	120
Rossendale	3	0.6272	121
Fullerton-Andover	5	0.6313	122
Bradford-North Brierley	10	0.6340	123
Runcorn	3	0.6467	124
Slough	7	0.6678	125
Wawlip	4	0.6766	126
Thurrock-Marsh Farm	1	0.6792	127
Swindon-Rodbourne	7	0.6885	128
Sedgeletch	2	0.7050	129
Nash	8	0.7390	130
Luton-East Hyde	7	0.7450	131
Wakefield-Calder Vale	10	0.7573	132
Rochdale	3	0.7696	133
Sheffield-Blackburn Meadows	10	0.7886	134
Davyhulme	3	0.8199	135
St Helens	3	0.8428	136
Huddersfield	10	0.8429	137
Leeds-Knostrop	10	0.8576	138
Derby	4	0.9535	139
Leek	4	1.2211	140
Halifax-North Dean	10	1.2597	141
Minworth	4	1.6543	142

Chapter 6.

Field Research Methodology.

Introduction.

At this point it is appropriate to take stock of the preceding work, and to ask how far this has taken us in answering the central question - 'can yardstick competition work'? Chapters 4 and 5 both addressed the issue using quantitative data. In those, however, we considered the narrower question of whether a tractable means of comparative efficiency measurement could be devised. Despite the limited data available we concluded that it could; subject to certain caveats and provisos.

The quantitative analysis yielded other results of some interest. It confirmed Shleifer's (1985) contention that regression analysis might be employed in the process, and that it is possible to arrive at an ordinal ranking of companies which is robust and gives some indication of the comparative efficiency of firms. Price variables were found not to be the crucial element in determining the cost function. Rather the effects of price were swamped by the effects of heterogeneous physical conditions represented by hedonic variables. Operational economies of scale were found to be exhausted at a fairly low level for water, and there appeared to be a wide variation in technical efficiency between operators in the sewerage industry.

The quantitative work also highlighted the importance of the cost of capital and the valuation of capital stock to the regulation of the industry. Historic cost measures were found to be unreliable and misleading. When current cost estimates of stock were included the effect was to swamp the estimate of total cost masking the effect of changes in operating costs. Overall, the value of the analysis lay in the fact that it added to the information set available to the Regulator. The fact that the extra information was imperfect did not invalidate the whole process (appealing to the results of Shavell (1979) and Holmstrom (1979))

Technically, then, we have demonstrated that one of the prerequisites of yardstick competition - comparative efficiency measurement - is possible. But this leaves many important questions unanswered. Questions which are not susceptible to quantitative analysis, but would enrich the understanding of yardstick competition considerably. In order to develop this understanding it is necessary to widen the field of study; to examine more closely the system as it operates in the English and Welsh water industry. From this it may be possible to establish general principles which would guide a policy maker towards or away from employing a similar regulatory solution in other industries.

Field Research: A Rationale.

Having utilised quantitative data in the early chapters a quite different approach is proposed for the last section of the work. The quantitative data used for the analysis of water and sewerage functions related to periods before privatisation of the ten Regional Water Authorities; before reform of the regulatory arrangements. Post-privatisation quantitative data could be employed; modelling in the same way as before. But it may be argued that this would add little to the analysis.

In order to develop the understanding of yardstick competition it is necessary to draw data from the industry post-privatisation; where, we argue, a system akin to that of Shleifer's was working. For this purpose, qualitative data is potentially a very rich source of insight, and one that remains relatively unexploited.

Qualitative data is, by definition, that which resists quantification and location within a framework fully described in terms of measurable dimensions. One temptation for the researcher more used to working with quantitative data is to succumb to a 'Gresham's law of research' whereby the quantitative drives out the qualitative. The predictable result is a reluctance on the part of the researcher to enter the field where the richest source of qualitative data lies. Historically this reluctance was not shared by many eminent political economists. Both Smith and Marshall were well acquainted with the business community and made frequent visits to the place of business, gathering information to inform their work. More recently, distinguished analytical economists such as Schmalensee (1989) have considered questions raised by adopting a case study approach to economic research.[128] Nevertheless there remains an imbalance in work published in leading economic journals in favour of analyses employing quantitative data acquired at one removed from the object of analysis.

Therefore a case can be made for the application of field research methods to economic phenomena. And field research is the means of gathering qualitative data for the final section of the thesis.

<u>Sampling.</u>

The aim of this fieldwork is to complement rather than duplicate earlier work, without sacrificing academic rigour in any way. The point is worth emphasising; for although

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[128] See also Lawson (1985).

the data of qualitative investigations are prose the analysis may be just as rigorous. The methodology employed in the analysis of qualitative data has been developed more extensively by practitioners within the allied disciplines of sociology, psychology and social anthropology. [129] And the general approach taken owes much to the work of sociologists Glaser and Strauss (1967). Nevertheless it is argued that a case can be made for the use of these methods in economic research.

The case for using qualitative data from field-work in the water industry rests on the argument that a field-study approach brings the researcher one step closer to the object of analysis. In other words, for the understanding of economic phenomena there is some advantage to be gained in first hand scrutiny of the water and sewerage operators. To date, little work of this sort has been undertaken for a regulated industry operating under yardstick competition. Much of the casual empirical evidence reported in the press falls far short of the high standards of rigour and sophistication set by theorists. Consequently, there is a place for formalising the approach to empirical work and improving the care with which observations are made.

The field of study comprised the 33 water companies of England and Wales[130] and the industry's Economic Regulator. The fieldwork undertaken was a series of semi-structured interviews with representatives of the various organisations. Given the constraints on time and funding for this labour-intensive fieldwork some method of sampling was required; although with such a small population there was scope for fairly extensive sampling. The method chosen

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[129] See for example Glaser and Strauss (1967), Lofland and Lofland (1984), Miles and Huberman (1984) and Strauss (1987).

[130] 10 Water and Sewerage Companies and 23 Water Only Companies.

was 'selective' or 'theoretical' sampling.[131] Technically, the key feature of theoretical sampling is that it should be organised consciously to suggest, develop and make precise theories about relationships. The conclusions about relationships drawn in this way are essentially qualitative. Glaser and Strauss (1967) emphasise the fact that with this method it is difficult to draw quantitative conclusions.

According to standard statistical sampling theory more data is preferred to less; thus reducing the variance of the sampling distribution.[132] But under theoretical sampling an increase in sample size is not necessarily useful. After a point, redundancy and inefficiency emerge as problems, where relevant data categories are exhausted or information is added to full categories. Consequently the sampling concentrates on filling certain 'core' categories. This may be done in many ways and may be labelled the 'slices of data' approach. This approach is taken to get different perspectives on categories or emerging hypotheses by various methods. Any unexplained exceptions and anomalies to the received theory allow falsification leading to a theory in its final form, which is stable in the face of new data and not troubled by unexplained counterexamples. Again, contrary to received theory, outliers are given close consideration as a source of useful information. To avoid overdetermination by collecting redundant or irrelevant data the field worker may be inclined to oversample around the tails of the distribution and to undersample around its centre of gravity. In this way the

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[131] Other methods discussed in the literature include 'opportunistic' and 'snowball' sampling. See Schatzman and Strauss (1973) and Glaser and Strauss (1967).

[132] Note the distribution of the mean has variance σ^2/n where σ^2 represents the variance of a large population and n is the sample size.

researcher aims to acquire especially informative data.

With theoretical sampling the process of data collection is guided in some sense by preconceived theoretical interests. In this there must be a balance between giving direction to the research and imposing certain theoretical preconceptions. Either extreme is unacceptable.

Instruments of Investigation.

As noted above the semi-structured interview is the 'instrument of investigation' or the means of carrying out the field-work.[133] Other possible instruments were considered but had disadvantages considered sufficiently serious to rule them out in this case. For example, postal questionnaires had the disadvantage of inviting low participation rates and being open to misinterpretation by the participant. Administered questionnaires were considered to be too rigid and closed to insights which might arise in less structured methods. A combination of instruments, so called 'multi-method' approaches were also infeasible given the constraints of time and funding. Therefore the semi-structured interview was used, built around an open ended agenda of questions with sub-questions or 'probes' attached to each. It encouraged consistency between cases, restricted the opportunity for researcher bias, and left room for unanticipated directions to be taken.

Having identified the field and established the semi-structured interview as the instrument of investigation the process of sampling began. The aim throughout the work was to gather qualitative information relating to the operation

[133] Dnes (1988) points out that Miles and Huberman (1984) are wrong to argue that the prior direction of field work will determine the instruments of investigation to be used.

of the regulatory regime for the water industry. To this end the process began with a letter to the deputy librarian of the Office of Water Services, who supplied current information on the key management personnel in each water company in England and Wales. From this list, an appropriate company interviewee was identified: ie the manager who had strategic responsibility for the activities of the company in relation to the workings of the regulatory regime. This person was generally designated 'finance director' or 'company secretary and accountant' for the smaller companies. Mr Ian Byatt, the Director General of the Office of Water Services was identified as the appropriate representative of the Economic Regulatory body.

Before finalising the sample a semi-structured interview agenda was drawn up for the companies but not the Regulator. This agenda picked up on the points raised by previous empirical work. Following Lofland and Lofland (1984) one guiding principle of agenda design was that no more than ten main topics should be covered. In this case, four were chosen. A delivery time of one hour was borne in mind when constructing the agenda; given that time commanded a high premium for the target interviewees and that the attention span of both interviewer and interviewee were limited.

The companies' final semi-structured interview agenda is reproduced as Appendix 1. This is a refined version of an earlier pilot interview agenda used in the first company interview and subsequently modified. It consists of four main headings, the leading general points, with sub-headings covering more specific areas of enquiry. These sub-headings were occasionally nested in hierarchical fashion to enable questions to proceed from the general to the specific in order to develop the understanding of certain points. Use of an interview agenda of this sort encouraged consistency in the questioning but was used primarily as an aide-memoire, a starting point, allowing the questions to be formulated and delivered more naturally in the interview itself. The open ended subheadings were used to enable unanticipated directions to be taken and unanticipated points to be developed.

With the working copy of the interview agenda in hand the process of sampling continued to the point of selecting the individual interviewees. Twelve out of the thirty three companies were chosen; the main selection criterion being representativeness. Geographically they covered the length and breadth of England and Wales; some serving scattered rural communities, others serving large conurbations; some having long coastlines, others being completely landlocked; some abstracted groundwater from water bearing rock strata, others drew all their reserves from surfacewater sources. Five of the firms sampled were water and sewerage companies (previously Regional Water Authorities), and seven were water only companies (previously statutory water companies). Ten of the twelve were part of the sample of companies used in Chapter 4's database. The other two 'outliers' in certain respects were added to increase sample size and enhance representativeness. As noted above the sample of twelve is a very high proportion of the total population of thirty three.

Having identified the companies in the sample and the key personnel I contacted each by letter. The letter was word processed, confined to one side of university headed paper, personally addressed and signed. In it I identified myself as a postgraduate under joint supervision. Brief, simple and specific details of the work conducted to date were given together with some intimation of the content of the interview. A time limit was stated together with an offer of a printed summary of recent work and a brief interview schedule. The summary interview schedule was a one-page document on headed paper containing a one sentence summary of each of the full interview schedule's main points. The researcher and supervisors were identified and an assurance of confidentiality given.

The reason for using a letter for the initial contact was to give the potential interviewee time to consider his participation and to signal the authenticity of the investigation. Frey (1983) gives evidence to suggest that pre-letters of this kind lower refusal rates and improve data quality. However, one week after the pre-letter every firm was contacted by telephone to ask whether arrangements for an interview would be made.[134] During this process a certain amount of tenacity paid dividends. Often several calls were made over a period of days. The result of this prolonged process of friendly attrition was a 100% response rate.

Although all the companies contacted granted personal interviews with officials, only seven of the twelve were with the finance directors or their equivalent. The remaining five were with managers reporting directly to the finance directors with special responsibility for regulatory affairs. Thus all interviewees had first-hand knowledge of the regulatory regime. The five regulatory managers had day to day and some strategic responsibility for these affairs within their companies. It may be argued that this weakened the sample. However it proved to be the case that the most appropriate company official was interviewed in each case. Where finance directors had little personal working experience of the regulatory regime

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[134] The telephone call was made to the interviewee's secretary, who, in most cases, organised the interviewee's appointments.

the task was delegated to someone who did. Given the central drive of the research, interviewees were without exception helpful and well informed.

The reasons for this very high response rate may be examined more closely. Certainly it is the experience of many researchers that personal interviews with high ranking company officials are very difficult to arrange. In this case, as with other academic studies there was no financial or publicity 'quid pro quo'. No monetary incentive was available and confidentiality was promised in all dealings. However, instrumentation and response rate do appear strongly linked. The semi-structured interview conducted on company premises was an instrument sympathetic to the functioning of the companies and in line with the usual means of communication employed by officials. One may speculate that questionnaires may have been received less readily. Identification with the University of Edinburgh was important as was the timing of the interviews. They straddled the General Election and came in the early part of the long run up to the price cap review. Therefore companies were anxious to derive as much information as possible about their comparative efficiency standing. Consequently the offer of research results may have had certain attractions.

Once all water company interviews had been completed a new semi-structured interview agenda was constructed for the interview with a representative of the Economic Regulator. It was a modified version of the earlier one and benefitted from the insights gained in the earlier interviews.(See Appendix 2) Its contents varied little from the previous version being comprised of a series of headings and sub-headings in hierarchical form as an aide-memoire in the interviews. Again, open headings were included to allow the interview to develop along unforseen lines.

A modified pre-letter was used to contact Mr Ian Byatt, the Director General of Water Services. He is popularly regarded as the embodiment of the regulatory authority, whose views in relation to the regulation of the English and Welsh water industry are unsurpassed in terms of authority. A more lengthy draft seminar paper was included and some mention made of the fieldwork conducted to date. Again a time limit was stated, but anonymity could not be offered for obvious reasons. All these measures were designed to signal a well organised approach to academic research. No 'secretarial attrition' was necessary in this case. Mr Byatt responded by telephone the following day and an interview was arranged.

The Interviews.

All the interviews were arranged by telephone and conducted at the offices of the water companies and Regulator at mutually agreed times. The company interviews were held between 7th April 1992 and 30th April 1992. The interview with Mr Ian Byatt took place on 20th May 1992.[135] The spoken responses to the questions asked were the raw data of the process and had to be recorded in some way. The preferred method was to take an audio tape recording of the proceedings. The advantages of this were the minimisation of data loss, accuracy and the fact that interviewees were not distracted by note-taking. However, there are some disadvantages, as Reid (1986) notes. They include: the inability to obtain informed consent for the use of the tape recorder; the interviewee who is guarded or inhibited by the recording; the passivity of the interviewer induced by this method; the expense of transcribing a large volume of data and the difficulties of handling it terms of assimilation and the detection of relationships.

[135] Full details of these interviews are contained in a confidential appendix available to the examiners.

The main alternative was the use of rough field notes made at the time of interview, supplemented by observations committed to paper at a debriefing session. Both methods were employed. Interviewees were asked to give their informed consent to tape recordings. Ian Byatt and seven of the twelve water company officials agreed. In all other cases interviewees permitted the taking of rough field notes by hand. Where interviews were taped notes were also taken to record details of interview environment and any other aspects not captured on tape.

The interviews lasted between three quarters of an hour and an hour. Space was left in this schedule to pursue any unanticipated points that were raised during each interview and to follow other lines of questioning. Without exception the interviews were enjoyable, good humoured occasions. The company officials were eager to talk at length, with varying degrees of conviction, about their company's operations. Punctuality and an organised approach to the interviewing both reassured the interviewees and aided later data reduction and presentation. On the evening of each interview a thorough debriefing was undertaken in which rough handwritten notes were expanded and written up in summary prose form. This was also the point at which other observations about interview environment and conduct were added. I found, in line with Schatzman and Strauss (1973) that memory of events did improve with practice. Also I became more discriminating in the comments committed to paper as the process went on. Much duplicated information was not recorded where handwritten notes were taken.

Having completed all the interviews the taped material was fully transcribed and the summary field notes attached. Although a degree of data reduction is an inevitable consequence of this process the tape recordings went some way to minimising data loss.

The result was a qualitative database comprised of the text of thirteen interviews. This is the data used in the following Chapter.

Appendix 1.

Company Semi-Structured Interview Agenda.

I] Background to Regulation.

I.1] The Regulator's statutory functions include the regulation of prices, to ensure duties are carried out in accordance with licence terms, to ensure companies could finance their activities, to protect the interests of customers and to promote competition, economy and efficiency. In his operation of the regulatory regime, does the Regulator prioritise these functions?

I.1.1] How / In what ways ? Examples

I.1.2] Why?

I.2] The RPI+K price cap formula was introduced to ensure 'arms length' regulation, but there remains a fine dividing line between monitoring activities and intervening in a company's management. Has the Regulator ever crossed that line?

I.2.1] Examples.

I.2.2] How has the scope of regulation changed since 1989?

I.2.2.1] Why?

I.2.3] State of relationship between the Regulator and the company.

I.2.3.1] Illustration.

I.2.4] Are strained Regulator-regulatee relationships an inescapable part of regulation?

I.3] Other.

II] Accounting Arrangements.

II.1] From the company's point of view, for what purposes do the (modified current cost) regulatory accounts convey more useful information than the historic cost accounts?

II.1.1] Strengths and weaknesses of modified current cost accounts against background of price cap regulation.

II.1.1.1] Main user groups?

II.1.2] Strengths and weaknesses of historic cost accounts against background of price cap regulation.

II.1.2.1] Main user groups?

II.2] How reliable are the accounting numbers registering capital stock, under both systems of accounting?

II.3] If RAG 1 (Regulatory Accounting Guideline Number One) were relaxed, but the RPI+K price cap formula remained in place would the company still produce some form of current cost accounts?

II.4] Does the Regulator have either an enthusiasm for, or an aversion to any one system of accounting?

II.4.1] Why?

II.5] Other.

III] Cost of Capital.

III.1] At the time of the initial K setting each company submitted detailed plans for capital projects and their funding. How have actual outcomes compared with these projections?

III.1.1] Physical variance.

III.1.2] Funding variance.

III.2] Attitude of company towards Regulator's 'Cost of Capital Consultation Paper'.

III.2.1] Politically as a regulatory device.

III.2.2] Content.

III.2.3] What are the short and long term consequences for the financing and operation of the company if it were to be implemented in its original form?

III.2.4] Do the proposals in the 'Cost of Capital Consultation Paper' signal an alteration in the way the industry is regulated?

III.2.4.1] Given the choice between price cap or rate of return regulation, which would your company prefer?

III.3] At the 1989 privatisation / K setting investors formed certain expectations concerning companies' financial and operating positions ie an unwritten contract between the government/OFWAT and the investors/companies. Has this 'contract' been altered since then?

III.3.1] How?

III.3.2] What prompted this?

III.3.3] Has this led to your view of the Regulator being altered?

III.3.3.1] Credibility of Regulator?

III.3.3.2] Regulatory risk?

III.4] Other.

IV] Comparative Efficiency Measurement.

IV.1] What comparative efficiency work has the company been involved in?

IV.1.1] Internal.

IV.1.2] With external agencies.

IV.1.3] Familiarity with econometric techniques.

IV.2] To what extent should measures of comparative efficiency influence regulation in general and the K setting process in particular?

IV.2.1] Acceptance of standard comparative efficiency measurement techniques, ie service standards etc.

IV.2.2] Acceptance of econometric techniques in K setting process.

IV.3] Do you have any view on the optimum size of a water company?

IV.4] In the regulation of the water industry it was assumed that local natural monopolies would persist, and a system of yardstick rather than market competition adopted. Can yardstick competition be made to work in the industry?

IV.4.1] To what extent does the industry operate under a system of yardstick competition at present?

IV.4.2] Has comparison with other companies in the industry affected the operation of this company?

IV.4.2.1] How?

IV.4.2.2] Competitive pressure felt?

IV.5] Other.

Appendix 2.

Regulator Semi-Structured Interview Agenda.

I] Background to Regulation.

I.1] Your statutory functions include the regulation of prices, to ensure duties are carried out in accordance with licence terms, to ensure companies could finance their activities, to protect the interests of customers and to promote competition, economy and efficiency. Do you see any of these as a priority?

I.1.1] Why?

I.1.2] Does each to these roles imply a different regulatory model?

I.2] The RPI+K price cap formula was introduced to ensure 'arm's length' regulation, but there is a fine dividing line between monitoring activities and intervening in a company's management. It has been suggested that the 'Cost of Capital' consultation paper was one example where the line was crossed. Would you agree?

I.3] Other.

II] Comparative Efficiency Measurement / Yardstick Competition.

II.1] In the regulation of the water industry it was assumed that local natural monopolies would persist, and a system of yardstick rather than market competition adopted. Can yardstick competition work in the industry?

II.1.1] How effective has yardstick competition been in the three years since privatisation?

II.1.2] Competitive pressure applied successfully?

II.2] In theory no more than two companies need be compared for effective yardstick competition but at present there are thirty-three companies in this industry. Would you emphasise maintaining the higher number or would you be happy to see the number come down?

II.3] OFWAT comparative efficiency work.

II.3.1] Familiarity with econometric techniques.

II.3.1.1] Attitude re potential impact on K setting process.

II.4] Do you have any view on the optimum size of a water company?

II.5] Other.

III] Accounting Arrangements.

III.1] Are there any purposes for which the historic cost accounts convey more useful information, either to the companies or to you, than the modified current cost accounts?

III.1.1] Other user groups?

III.2] Enthusiasm for CCA?

III.3] In your conduct of regulation I have gained the impression that you attempt wherever possible to draw together ideas from the separate disciplines of economics and accounting. For example in the construction of modified current cost accounts, the moves against cross subsidisation and towards marginal cost pricing. Is my impression a correct one?

III.3.1] How successful do you think you have been in this?

III.4] Other.

IV] Cost of Capital.

IV.1] At the 1989 privatisation / K setting, investors formed certain expectations concerning companies' financial and operational positions ie an unwritten contract between the government/OFWAT and the investors/companies. Has the 'contract' been altered since then?

IV.2] Has regulation moved away from price cap to rate of return?

IV.2.1] Does 'cost pass through' have a place in a price cap regime?

IV.2.2] Would it be fair to characterise the regulatory regime as five or ten years price cap, then at the end of that period a rate of return exercise, then another period of price cap etc?

IV.3] Attitude of Regulator to reactions of companies to 'cost of capital consultation paper'.

IV.4] Other.

Chapter 7.

Field Research Results.

Introduction.

The analysis of the final substantive chapter is built on the qualitative data gathered from interviews with water company and regulatory officials over the period April - May 1992. Although the interview schedules were divided into four sections the material will be presented in two parts.

In the first we will attempt to supplement and develop the discussion of the 'hallmarks' of yardstick competition begun in Chapter 2. Specifically, this will throw some light on the way in which company officials and the Regulator understood the terms 'comparative' and 'yardstick competition'. In addition it may enable us to assess the extent to which the public and private pronouncements of Regulator and Industry on matters of regulation were aligned.

In the second we will tackle two further issues; the cost of capital and regulatory relationships. The cost of capital was highlighted as a key question in earlier chapters of the thesis, when considering the means of comparative efficiency measurement. Results were shown to be sensitive to the particular capital valuation convention adopted. Furthermore, it was argued that the omission of capital cost seriously undermined the plausibility of econometric results for this capital intensive industry. In the run up to the 1994 periodic review the cost of capital remains the focus of a vigorous debate between the water companies and their Regulator.

Regulatory relationships have been the subject of much press speculation since privatisation. Given the nature of the final settlement the question was, and remains, important for economic policymakers as well as industry officials. With qualitative data it may be possible to explore some of the ways in which personal dynamics have shaped and driven the regulatory system. Conclusions will be tentative, but the discussion may go some way to fulfilling the general aim of the thesis; which is, to analyse and develop the understanding of yardstick competition as it operates in the English and Welsh water industry. With these observations it may be possible to derive certain general principles on which policymakers may base their decisions concerning the regulation of other industries.

The Hallmarks of Yardstick Competition.

One of the conclusions of Chapter 2 was that whilst the final regulatory solution for the industry embraced the principle of yardstick competition, the system was not operable at the time of privatisation. As the regime developed, however, it became clear that the principle influenced many subsequent policy initiatives of Ofwat.

Returning briefly to the earlier discussion, several aspects of the emerging regulatory regime 'hallmarked' it as one embracing yardstick competition. For example, the system, derived from that outlined by Littlechild (1986), employed a price cap[136] which would be reset at 5 or 10 year intervals taking into account the comparative performance of companies. References made to the Monopolies and Mergers Commission were subject to the new public interest clause which rejected consolidation if the

[136] Although cost pass through and periodic review provisions ensured the settlement deviated in some ways from pure price cap.

Director's ability to make comparisons between companies would be prejudiced. Ofwat's data gathering and validation work was motivated, at least in part, by the need to compare company efficiency. A 'comparative competition' post within the Charges Control Division of Ofwat was established. The 1989 Ofwat Annual Report gave a classic policy statement affirming the view,

> "I [Byatt] shall compare the performance of the 39 appointed companies and use the examples of the best to set standards for the others to introduce an element of comparative competition. Such comparisons will cover differences in operating cost, capital cost, levels of service and 'customer care'. There will be allowances for differences such as geographical conditions which are outside the control of effective managements. These comparisons will help me to achieve a better deal for all water customers in England and Wales."[137]

Ian Byatt's subsequent public announcements confirmed this.

> "My ability to make comparisons between different water companies is an essential part of my duties under the 1989 Water Act." [138]

In his interview, the Regulator confirmed that a system of comparative or yardstick competition was being developed but that there were substantial difficulties with its implementation. Several company directors pinpointed the inability of the Regulator adequately to control for company heterogeneity as the chief stumbling block. However, in the majority of interviews it was suggested that there were in fact two main difficulties over the working of the system. And that these were the ones suggested by Shleifer (1985): namely heterogeneity and susceptibility to strategic manipulation.

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[137] Ian Byatt, Ofwat Annual Report 1989 p11.

[138] Ofwat Press Notice 34/90, 4/7/90.

Although company officials recognised and applauded much early work on 'explanatory factors' undertaken by Ofwat[139], the technical issue of controlling comparators for heterogeneous circumstances was perceived as being unresolved. Many mentioned the inadequacies of the system at the time of the privatisation of the Water Authorities. They argued that the 'playing field' on which comparisons had been made was 'sloped against' their own company in various ways. Every company suggested ways in which it was unique. Most common among the features mentioned were geographical location, financing arrangements, water sourcing and the customer base. But in several cases it was difficult to take these arguments at face value. This was due to an awareness of the second problem mentioned by Shleifer (1985) - strategic manipulation.

In a principal-agent setting such as we have in the English and Welsh water industry, it is clearly in the interests of companies to try and win concessions from the Regulator. In this context it may involve the setting of a more relaxed price cap or the granting of interim determinations. Given that the Regulator has accepted in principle that allowances must be made for companies facing widely differing operating environments, the incentive is for companies to use this to their advantage. Therefore companies may make as much of the heterogeneity issue as possible when discussing regulatory arrangements with Ofwat. It is in the Regulator's interests to make allowances for heterogeneity, but then to ignore the further pleadings of the companies and encourage them to meet their charging limits through cost minimisation.

Whilst both sides admitted that the technical issue of

[139] The 1991 Ofwat Annual Report (p93) lists the members of the various working groups established to examine this and other issues.

accounting for company heterogeneity had not been completely resolved companies were more openly unhappy with the current means of comparison than the regulator. But whilst some of this may be quite justifiable I was unable to assess the extent to which these arguments were part of the process of strategic manipulation: whether or not this was a conscious or unconscious decision by those interviewed.

One practical way in which the Regulator could get around his inability to control for company heterogeneity was suggested by the finance director of a water only company. He argued that different licence arrangements were required for different categories of company according to their size. Other water only company officials supported the view arguing that Ofwat now demanded a very large quantity of detailed information for regulatory purposes. In Shleifer's terms these officials were putting forward one particular 'heterogeneity' argument. As expected, it was the smaller companies that regarded the demands as especially onerous and inequitable, given that the larger companies were required to supply very similar information. The larger companies had an advantage in being able to spread the fixed costs of this information gathering over their larger personnel base.

The Regulator was aware of the issue, but the process of interviewing revealed very clearly the extent to which this was a problem. The contrast was striking. In the Water and Sewerage Companies, regulatory matters were invariably dealt with by a specialist team reporting to a single board member or official. In this, their sole task was to administer and direct company regulatory policy. In several small water only companies it was not unusual to find one man, often the company secretary and accountant, dealing with this alone. It was in these companies that the argument for licence concessions was made most vigorously.

Overall, from the Regulator's point of view, there appeared to be a tension between maintaining a clear, equitable and effective method of regulation on the one hand, and of allowing sufficient flexibility in the regime to deal with company heterogeneity on the other. Or simply, it was in the companies' interests to 'flex' the Regulator's yardstick, and it was in the Regulator's interests to resist.

Against such a background the potential for conflict and indecision was enormous. The fact that the Regulator was not locked in perpetual conflict with the industry was put down to his personal skills, and also his attitude towards the conduct of regulation by yardstick competition. An important aspect of his approach was highlighted during the interview and confirmed by extensive reading of the official publications of Ofwat. It is that the Regulator seldom refers to the principle of 'yardstick competition' preferring the term 'comparative competition'.

Taken at face value the observation is insignificant, almost trivial. In the conduct of regulation Byatt clearly follows the approach labelled by Littlechild (1986) as 'yardstick competition'; however imperfect the scheme may be at present. Nevertheless he consistently avoids the use of the term. He explained his preference in the following way,

> "I think that yardstick competition...I'm not sure that's the word I quite like because it suggests there's a yardstick against which you measure things and I'm not sure that there is. But some comparison of the performance of companies is a good deal better than having no ability to compare in a situation where you have a monopoly which is likely to persist" [Byatt]

This confirmed the impression gained from the literature that, as Regulator, he was reluctant to use the term 'yardstick'. The word, he believed was 'loaded' in the sense that it implied the possibility of deriving absolute rather than relative measures of efficiency; cardinal rather than ordinal rankings. He recognised that the techniques for comparative efficiency measurement were, as yet, rather imperfect. Therefore, whilst he embraced the principle of yardstick competition and sought to apply it in his work, his preferred terminology for the process was 'comparative competition'. Consequently, comparisons would be indicative of relative efficiency rather than the last word in the debate.

In one sense this careful use of language may go some way to signalling to the companies his awareness of the imperfections of any set of company comparisons. By so doing the Regulator may have diffused some of the tension spoken of earlier, by indicating a willingness to adopt a flexible approach to the issue of comparative competition. Inevitably, perhaps, this 'flexibility' did not go far enough to satisfy the various company officials who were interviewed. They generally regarded the whole process with a discomfort bordering on suspicion. And again they expressed concerns that the Regulator was not fully aware of the imperfections of any set of company comparisons. (The point will be returned to later when discussing the issue of regulatory capture.)

Thus the general picture of regulation may be crudely characterised as one in which the Regulator sees the company comparisons as flexible tools to be used sparingly in the task of regulation; whilst companies see the comparisons as threatening, inflexible devices which would direct and inhibit their operations. So although both parties were agreed that the regime was at an early stage of development different attitudes were held towards it.

The Initial Settlement.

The regulatory settlement put in place in 1989 was not, of course, of Ofwat's making. K values which fed into the RPI+K price cap were set by the Secretaries of State for the Environment and Wales. So it was the Government, rather than the new independent regulatory authority that set the industry's course for the first five years.

The financial arrangements were ostensibly organised with a view to providing companies with sufficient funds to finance large investment programmes and to encourage the efficient allocation of resources. However, several finance directors expressed the view that the initial K settings reflected a quite different agenda. They believed that in this the new Director General, Ian Byatt, had little or no input; the key decisions being taken by those working through the Department of the Environment. Consequently,

> "He [Byatt] thinks the K's are too high. They were too generous. The companies pulled the wool over the DOE's [Department of the Environment] eyes by throwing the kitchen sink into the book of numbers; and inevitably there's some truth in that" [Finance Director (FD)]

It was suggested that these K values were justified on the basis of expected investor requirements rather than on what the industry Regulator regarded as appropriate. This was apparently confirmed in the Ofwat Cost of Capital consultation paper (July 1991) which noted that company profit before tax in 1990-1 was 20% and operating profit 12% above the expectations of the Secretaries of State when they set the initial price limits.[140]

Several finance directors were of the opinion that Byatt's

[140] 'Cost of Capital : A Consultation Paper' Ofwat, Birmingham, July 1991 vol 1 piv.

"hands were tied" at the time of privatisation and that the Government had erred on the side of a generous K for reasons of political expediency. Chief amongst these was the need to ensure the successful floatation of the ten water authorities who were in a politically powerful position in the run up to privatisation. Others said motivations included the need to give companies sufficient "headroom for manoeuvre" because of the inaccuracies in the initial survey and comparison of operating conditions, undertaken by the Government's consultants, Deloitte Haskin and Sells. Officials of the water only companies believed the initial settlement with its write off of substantial water authority debt (the 'green dowry'), and the prospect of privatisation proceeds going directly to the exchequer had been prejudicial to their position. Nevertheless Ian Byatt had done the best he could with the "poisoned chalice" of a settlement he had inherited.

Since then it was suggested that Byatt had set about redeeming the regulatory position, with a series of measures designed to reduce the scope for strategic manipulation of information. In this he apparently met with considerable success as a finance director of one of the water only companies explained.

Before 1989 the statutory water companies had collaborated very closely and had exchanged information freely with each other. But any continuation of such a scheme would clearly threaten to undermine a reformed regime embracing the principle of yardstick competition. It was therefore imperative that this informal 'informational cartel' between the statutory companies was broken. This would in turn limit the scope for the strategic manipulation of information by groups of companies. The reformed regulatory regime and the new environment in which companies operated apparently achieved this. A finance director still in post following the 1989 reforms recalled the previous position with enthusiasm and affection,

> "Within the statutory companies until the ownership changes took place there was a very, very free exchange of information. It was a delightful industry to be involved in. Because rather than being in competition we actually saw ourselves working together in a very pleasant way. So that when we had a problem here we would talk to one of the other companies to find out what they were doing to solve the problem" [FD]

But under the new regime this position had been altered. Companies previously unaware and unaffected by competitive pressures were disturbed by the new rigours of yardstick competition. By setting performance targets with reference to comparative efficiency measurement the Regulator had, at a stroke, removed the incentive for collaboration. The informal cartel of the statutory companies was broken.

Another example offered of the way in which the Regulator sought to redeem the regulatory situation was his intervention on several occasions to persuade companies not to increase prices by the full amount allowed under the price cap[141]. With the 1994 periodic review being the responsibility of Ofwat rather than the government, company officials saw the exercise as something of a watershed. At that time they argued that Byatt would be able to clear away many inadequate controls which he inherited and to put in place new, tighter, price caps set in line with publicly announced criteria. This, they hoped, would reduce the scope for regulatory intervention over the next five or ten years.

<u>The Effects on Competitiveness.</u>

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[141] The issue of 'voluntary abatement' was discussed by Ian Byatt in the Ofwat Annual Report 1992 p9.

The new regulatory regime, by breaking the informational cartel and introducing company comparisons had implications for company competitiveness. The first clear message from a majority of interviewees was that the comparative element of the yardstick regime had improved performance incentives. One finance director said,

"There is no doubt that the incentives to become more efficient have become more effective. This company has been reducing head count for example, significantly, in order to drive down operating costs and to drive up profit. And it's most unlikely that sort of change would have taken place if we'd remained in the public sector. Which I think is clear evidence that the idea of price caps and becoming more efficient is working." [FD]

Several companies cited the comparative efficiency exercises as prompting them to reexamine all areas of their operations with a view to achieving greater efficiency. Yardstick competition had been a spur to management and the means whereby regulatory pressure was being exerted. Consequently what had previously been parochial approaches to water company functions were now being reviewed in the light of national information.

A strong connection was made between the delivery of yardstick competition and the use of the price cap. One finance director saw the two as being inextricably linked.

"I think the first thing you've got to say is that if you sign up for a price cap regime then you have to make yardstick competition work, because it is the absolute essence of price cap. The efficiency factor is built into the formula. Otherwise there is no benefit to the customer." [FD]

In other words, even this very limited form of yardstick competition, imperfect and at an early stage of development, was delivering results. These results included increased competitive pressure on the companies and the recognition that benefits accrued to customers from the use of the system in conjunction with a price cap. This evidence ostensibly confirms Shleifer's contention that there were benefits from a yardstick solution. It runs contrary to the criticisms of Stelzer (1988) mentioned in Chapter 2.

The responses were unsurprising in the light of the sample of interviewees. Officials of publicly quoted companies would be unlikely to reveal their doubts over company efficiency whether or not anonymity was assured by an interviewer. However, it would be wrong to discount completely their observations concerning increased competitive pressure. Whether or not this has led to improved company performance, however defined, is another question. No quantitative evidence was presented by interviewees to support the argument that increased competitive pressure had led to improved company performance. But a majority of interviewees did suggest quite firmly that this was the case.

In order to attempt to gain some further insight into this view using quantitative data, one of the points mentioned by an interviewee as an indication of increased efficiency was examined. The reduction in numbers of employees was cited as a tangible result of increased competitive pressure since privatisation. Table 7.1 below gives time series data for the English and Welsh industry compared to its Scottish counterpart; which did not experience institutional reform over the last ten years.

Table 7.1.

Manpower.

	EMPLOYEES[142]		EMPLOYEES PER UNIT OUTPUT[143]	
YEAR	ENGLAND & WALES	SCOTLAND	ENGLAND & WALES	SCOTLAND
1981/2	70,852	6,318	4.48	2.79
1982/3	68,955	6,226	4.25	2.77
1983/4	66,551	6,121	4.07	2.74
1984/5	63,175	6,144	3.83	2.79
1985/6	59,606	6,129	3.59	2.78
1986/7	57,502	6,155	3.41	2.80
1987/8	56,774	6,270	3.36	2.79
1988/9	55,356	6,194	3.28	2.81
1989/90	54,653	6,094	3.16	2.71
1990/1	53,318	6,229	3.06	2.71
1991/2	54,110	6,230	3.14	2.75

Source: Waterfacts 1992, Water Services Association.

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[142] Full time equivalent employees at 31st March. Note figures for England and Wales include employees of statutory companies; those post 1989 include numbers employed by the newly established NRA (National Rivers Authority). It took over some of the functions of the Regional Water Authorities and most of its staff transferred from the Water Authorities.

[143] Employees per megalitre of water supplied per day. Note that the denominator just captures one aspect of the companies' activities. Sewerage and other functions are omitted in this measure.

The evidence for a marked reduction in head count post 1989 for the English and Welsh companies is rather unclear. Indeed employee numbers have reduced consistently from 1981/2, and there appears to be no structural break on or around 1989. The measure of employees per unit output has also reduced year on year; although great care should be taken in interpreting this statistic as it merely reflects water supply activities.

Three points do, however, come out from the table. Firstly this steady reduction in employee numbers in England and Wales contrasts with a more stable pattern for Scotland where no consistent reductions are made. Secondly, figures for 1991/2 show a sharp rise. This may be due to the diversification policies of newly privatised companies which meant that other going concerns were bought, which in turn raised the head count. Thirdly, there may be some minor structural break in the English and Welsh series between 1984/5 and 1985/6 where the decline in employee numbers is most marked. This is around the time at which privatisation of the RWAs first came onto the policy agenda of the Government. Consequently companies may have begun to take more vigorous action to reduce employees from that time onwards.

Returning to the interviews it was noted that the trend towards the takeover and merger of water companies would inhibit the future development of the process of making comparisons. Ofwat's policy towards mergers was set out clearly in the 1989 Annual Report,

> "Mergers between existing water enterprises in the UK and the integration of their management would reduce the number of comparators and prejudice my ability to make valid comparisons. I recognise, however, that there may be public benefits which could outweigh such a detriment." [144]

[144] Ian Byatt, Ofwat Annual Report 1989, p11.

During the interview Ian Byatt repeated the official line but then added an interesting rider,

> "In order to get good comparisons I would like to see the number stay up. And any reduction in the numbers is going to lose something in the way of ability to compare because there are obvious differences in the environments in which the companies operate. So you've got to allow for those, and you soon run out of degrees of freedom in this game. And in the case of the dirty water, indeed work done by Deloittes at the time of privatisation was a good deal less successful than the case of clean water and that may have been because of the larger number of companies. There may sometimes be arguments for reducing the number of companies, if for example you can have such a gain in efficiency that it outweighs the ability to compare. Not a very easy trade off but that came up in the Three-Valleys case in front of the MMC [Monopolies and Mergers Commission]. The MMC took a view about the trade off and made recommendations and then the case came back to us and I suppose we took a view about the trade off. We said it was satisfactory for prices to go down by ten per cent and to lose possibly two comparators. But that relationship isn't a linear relationship. So the more we lose companies, the more the number of comparators falls, the bigger the loss in terms of ability to compare." [Byatt]

The significant issue from the point of view of yardstick competition in all of this is the argument that there is a non-linearity in the relationship between the number of comparators and the ability to compare companies. Strictly, of course, only two comparators are needed for Shleifer's regulatory system to work. Thus by retaining a preference for a greater number of comparators the Director General departs from the strict requirements of yardstick competition. However, the retention of a greater number is a pragmatic compromise between the demands of pure theory and those of institutional reality. It is made necessary by the fact that the systems of comparative efficiency measurement are insufficiently robust to support yardstick competition in all its purity. Informational requirements are such that a relatively large number of comparators must be retained in order to supply sufficient information on differing operating environments to allow reliable comparisons to be drawn.

In an ideal world, with two identical firms serving different areas with common features the Regulator would presumably allow mergers to proceed until only two firms were left and then put an absolute halt to the process. Instead he has signalled a growing reluctance to sanction mergers as the number of independent firms continues to decline.

Outlook for Yardstick Competition.

All interviewees offered opinions on the future development of yardstick competition in the industry. Two contrasting views emerged. The first, minority view, was offered by only one of the finance directors. He suggested that the problem of accounting for heterogeneity was simply too difficult to solve. Consequently comparisons would be too difficult to draw and that different licence arrangements would be required for different companies. Several finance directors pointed out how theoretically seductive the idea of yardstick competition had been, but how practically difficult the system was to implement. One said of the initial comparative efficiency exercise,

> "I don't know whether you tracked the Deloitte study that was done in 1989, but that's really the process they went through. Initially they thought 'this is nice and easy. Stage one you produce a framework, stage two collect all the data, stage three Bob's your Uncle ! You just rank all the companies and press the efficiency button'. Of course it degenerated into a horrendous exercise. But at the end of the day, efficiency factors were built into the K, however sort of arbitrarily." [FD]

The second view was more widely held. It was, in essence, incrementalist. Those taking this line openly acknowledged the difficulties inherent in the whole process of regulation, but maintained that to sidestep the issue of comparison would be to diminish the concept and working of yardstick competition. The view was pithily summed up by one interviewee,

> "OK we may have made some wrong decisions, but we'll get better next time" [FD]

The development of improved information flows and the harmonisation of accounting practices led many companies to believe that the 'playing field' on which comparisons were being made was becoming more level over time. Consequently, yardstick competition, which was working in only a very limited way, would continue to gain acceptance and become a more accurate regulatory tool. In other words, the situation would improve over time as data and analytical techniques were developed. Ian Byatt shared this broadly optimistic view, whilst acknowledging the difficulties.

> "Pinning down exactly why costs vary is a more difficult activity, but the great range of prices which they have suggests that there is scope for looking at where people are more or less efficient" [Byatt]

Other evidence to suggest the incremental improvement in the means of regulation was offered. This included Ofwat's comparative efficiency studies[145] which progressed slowly through a series of technical committees and comparative efficiency working groups preparing reports for company comment. Several companies, particularly the large water and sewerage operators had representatives on these bodies. The larger companies with their regulatory teams, undertook additional internal work to shadow the Ofwat studies as a proactive management strategy. The smaller companies, particularly those in which the company secretary and accountant dealt with all regulatory matters, frequently undertook no formal comparative efficiency work for fairly

[145] Information on their progress was issued by way of 'Dear FD' letters. FD19,22,33,38,41,49.

long periods of time. One view expressed was that this sort of work was best left to the 'higher bodies'[146] and those with the resources to finance these policies. However, all confirmed that they used informal performance comparisons even if it was as basic an exercise as comparing company dividend levels.

It should be noted that the considerable variation in the amount of comparative efficiency work undertaken by companies could potentially undermine the working of yardstick competition. This would be the case if it led to companies forming information cartels of the sort employed by the statutory companies before 1989. Equally, if the companies possessed superior comparative efficiency information to the Regulator then problems would arise. The evidence was that, for the foreseeable future, this does not appear to be the case. The incentive structure is such that it is not obviously in a company's interests to collaborate on comparative efficiency work with a counterpart. Even the most rudimentary system of yardstick competition ensures that this is the case. Moreover, Ofwat has driven much of the comparative efficiency work involving industry representatives and leads the industry in terms of expertise.

The overall impression gained from interviewees was that yardstick or comparative competition was an important feature of the regulatory regime that would become more significant in the future. This would be due, in part, to the steady improvement in the techniques available to analyse improved industry data. Whilst companies accepted this, they were apprehensive that the Regulator would be tempted to use the tool in an inflexible way, not taking sufficient account of company heterogeneity. The Regulator

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[146] Meaning the Water Services Association and Ofwat.

had been at some pains to dispel this notion, but it remained and emerged in the public and private comments of company officials.

The Outstanding Issues.

Two further issues of particular importance to the concept of yardstick competition were addressed specifically in the interviews: the cost of capital and regulatory relationships.

Cost of Capital: Current Cost Accounting.

The empirical work of chapter 4 demonstrated quite clearly the importance of the cost of capital to any comparative efficiency analysis of this sort. In a capital intensive industry with very long asset lives it was unsurprising that results were shown to be sensitive to the particular capital valuation convention adopted. Furthermore it was argued that the omission of capital costs seriously undermined the econometric results.

Under s7 of the Water Act 1989 the Regulator was given a duty to ensure that companies could carry out and finance their functions. This required that the cost of capital be set high enough to attract private funds. At one level the setting of the cost of capital is a purely technical question. But it became clear from the interviews that the whole issue had become highly politicised.

The better than expected company profits in the first couple of years following privatisation sparked a lively debate over the appropriate means of setting the cost of capital and its level. Much press comment, hostile to the companies and the Regulator, reinforced the perception that companies were earning supernormal profits, and that returns to shareholders were in excess of those necessary to induce them to retain their shares. In July 1991 Ofwat responded to its critics by addressing the whole cost of capital issue in a consultation document. The document argued that there was no prime facie reason why investors in the water industry should be rewarded with returns in excess of those generally available in the financial markets. The paper went on to set out reasons why they considered an appropriate return on equity in the water industry to be between 5% and 7% in real terms.

This move provoked the industry to make a robust response. In a joint document by the Water Services and Water Companies Associations (November 1991) they argued for a 9½ % real cost of capital. In welcoming the Regulator's support of an incentive-based approach to economic regulation, they opposed any 'drift' in the regulatory system towards one that involved annual or frequent intervention in the agreed price cap on the basis of ex post rates of return which were actually achieved. A third Ofwat paper (November 1992)[147] moved the debate forward again in presenting a discussion of the framework for reflecting reasonable returns in the periodic review. It complemented the previous paper in raising the question of how to establish a value for each company to which the cost of capital could be applied. A value which would properly reflect the capital attributable to investors and creditors.

Whilst time precluded questioning over the technical issues raised in these and other documents, two points at the heart of the debate were discussed in the interviews. These were current cost accounting and regulation by rate of return or price cap. The choice was made, firstly, because

[147] 'Assessing Capital Values at the Periodic Review', Ofwat November 1992.

they were questions of central importance to the debate over yardstick competition. Comparisons are influenced heavily by the particular accounting conventions adopted, as was seen in Chapter 4. Yardstick competition and use of the price cap have both been part of the move towards an incentive-based approach to economic regulation. The second reason was that the views of the company officials promised to yield material relevant to debates being conducted in other recently privatised capital intensive utilities. Thus, many rather esoteric, and industry-specific, questions of asset valuation were set aside.

In the post 1989 regulatory regime one of the main innovations, and consequently one of the main bones of contention, was the requirement for companies to prepare a set of regulatory accounts on a modified current cost basis, alongside the legally required historic cost statements. And although the system of accounting now used differs in some ways from that of SSAP 16[148] its general approach is the same. Ian Byatt was enthusiastic that this was the appropriate way to report the economic activities of companies in the industry. In the 1990 Ofwat Annual Report he made the point.

> " A key decision has been to change the basis on which current cost accounts are produced, to be based in future on the concept of Financial Capital Maintenance. I am confident that these guidelines will generate accounting information which will be of greater value to the management of the companies and will also provide me with a reliable basis for the comparisons of performance which are central to the regime."[149]

As the statement made clear, the Financial Capital Maintenance (FCM) concept was established as the foundation

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[148] Statement of Standard Accounting Practice 16, Current Cost Accounting.

[149] Ian Byatt, Ofwat Annual Report 1990 p12.

for the new current cost reporting.[150] This was deemed to be more appropriate than the competing Operating Capability Maintenance (OCM) concept. Under FCM, profit was measured after allowing for maintenance of the purchasing power of the business' opening financial capital. Operational assets were to be valued at their current replacement cost. This involved the use of a general inflation index, such as the RPI. The emphasis of the approach was therefore on maintaining the real financial capital of the company with its ability to finance its functions. In this, FCM addressed the principal concerns of the shareholders of the company[151].

The alternative OCM approach was rejected. This would have shifted the emphasis towards maintaining the physical operating capability of the assets of the company. Under OCM profit would have been measured after provision had been made for replacing the output capability of a company's physical assets; typically using a specific inflation index. The approach would have addressed the major concerns of company management rather than shareholders. This idea underpinned SSAP 16 and is the main point at which the system of accounting adopted in the industry differs from the current cost accounting of the previous decade.

Byatt argued that the modified system of current cost accounting gave comparable measures of the real costs of supply including the cost of capital across companies. It avoided the main problems of historic cost accounting which were especially acute when considering returns on capital in a capital intensive industry with long asset lives. In

[150] See Appendix.

[151] Note, if there is no general inflation real FCM is equivalent to conventional historic cost accounting with the exception of the treatment of unrealised holding gains.

the presence of inflation these included understated asset values, overstated profit measures and distorted measures of total costs. The FCM system, he argued, also led to realistic assessments of asset values and trends in the returns earned on the assets. From a management perspective the annual 'July Return'[152] of information to his office was intended to be a monitor of operating capability. Consequently he deemed it unnecessary to reflect OCM concepts in the current cost accounts. Most importantly, he regarded it as being appropriate that the companies publish accounting statements which were consistent with the economic framework in which they were regulated.[153]

Clearly there is an inherent logic in a system that regulates through the use of a price cap which employed the Retail Prices Index (RPI), and required accounts to be prepared on an FCM basis that used the RPI as its general inflation index. In addition there would appear to be an incoherence in accepting an RPI+K price cap but continuing to report using historic cost accounts exclusively. In setting price caps the Government worked under the assumption that it was the customers who should fund the replacement of capital stock through increased real prices. In contrast, the implied assumption underlying historic cost accounting is that capital funding is derived from the stock and loan markets. Intellectually then, the arguments appear weighted towards Byatt.

However, although Byatt was enthusiastic about this accounting solution, interview evidence appeared to

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[152] An annual return of information made by companies to the Regulator in fulfilment of the terms of their licences. The return includes information on output and performance and progress on capital expenditure programmes.

[153] Full details of the system of accounting are contained in the Regulatory Accounting Guideline (RAG) 1.01 published by Ofwat.

indicate that he was at variance with the rest of the industry. Anti-current cost sentiment ran high. And whilst company officials generally accepted that the system was slightly more satisfactory than traditional historic cost accounting, (or the SSAP 16 approach) in theory, they said that the practical implementation of it had proved very troublesome. One official summed up the view by stating that as high theory, it was acceptable for academics but not for practitioners. He went on,

> "I'm not getting particularly excited about the current cost accounts. I'm fairly annoyed that we've got to produce them because its a drain on our resources" [FD]

Most concern was expressed over the compilation of inventories of physical capital stocks. In general it was found that the larger water and sewerage companies were a good deal more sceptical about their inventories that the water only companies. In several cases the large companies indicated that inventories were fairly inadequate and that capital valuations had been undertaken on the basis of some quite limited sampling. In stark contrast, the finance director of one small water only company maintained that the capital asset valuations were excellent and that a full inventory of fixed assets had been maintained. The reason for this may lie in the fact that only the better-run statutory water companies were able to continue operating after the 1974 reorganisation of the industry. Consequently the ten Regional Water Authorities inherited a good many incomplete records from less well organised bodies.

Despite their continued reservations over valuation all interviewees were agreed that historic cost figures were seriously flawed. Consequently, they argued, customers were being misled by the reported profit figures. However they considered that over time the records of physical capital stock and hence current cost measures would improve. But despite this, for the moment the valuation of capital stock was,

"In the right ball-park" [FD]

So although the new system had theoretical merits, there was a question over the consistency of approach taken by various companies.

Given this response further analysis of the data was undertaken to see whether other reasons for the lack of enthusiasm for this form of current cost accounting could be uncovered. The majority of interviewees were trained as accountants. As such they were aware of the whole inflation accounting debate conducted over the last couple of decades. They were also aware that, in the end, the profession was unable to come to one mind on the matter; and as the problem of inflation slipped down the agenda so did the current cost accounting debate. This staffing situation may go some way to explaining why those trained primarily in the preparation and interpretation of historic cost accounts felt unenthusiastic about the others.

Some interviewees revealed that, for the management of companies, the modified system of current cost accounting was seldom used. Despite its obvious flaws the historic cost accounts were more widely employed and understood. Significantly, the majority said that, if the Regulator relaxed the requirement for the modified current cost accounts, the companies would cease producing them. Apart from the fact that they found little value in them for management purposes, the company finance directors believed that the 'City' did not understand or use current cost accounts. They maintained that shareholders were only interested in historic cost profit figures (even though they recognised how misleading they could be); and that the fact that the accounting profession as a whole was unable to resolve the issue previously was evidence of how complex the technical and conceptual questions were. Only one finance director suggested rejecting both systems in favour of a cash-flow basis for reporting.

Only in the context of the regulatory regime were the accounts said to have much value. Even here, several officials argued that Ian Byatt had taken an 'economic' approach to an 'accounting' problem. They pointed to his previous work in the Treasury[154] and argued that he had been unsuccessful there in drawing together the accounting and economics disciplines. They pointed to the suspension of SSAP 16 as evidence of this. Nevertheless they viewed his commitment to this new system of accounting as total, and his enthusiasm for it as bordering on evangelical zeal. One official said that he was,

> "Totally sold on it" [FD]

Others portrayed him as someone leading a one-man campaign to convert the 'City' from historic to current cost accounting and thereby bring a system, similar to one rejected a decade ago, back into fashion. One finance director was adamant that his company would not be part of any such movement; and his view of the City's probable response was equally muted,

> "The City is not going to turn itself on its head for just one industry or one person. So even though he will certainly want current cost accounting to provide the principal method, he will continually have to have regard to the historical cost indicators and will have to change the K factor in my opinion if necessary to reflect that."[FD]

[154] Ian Byatt chaired the Advisory Group which produced the report 'Accounting for Economics Costs and Changing Prices: A Report to HM Treasury' in 1986.

Others saw the Byatt system of current cost accounting as a parochial water industry solution to the wider problem of accounting for capital costs in times of rising prices. But despite this they believed the system would not be radically reformed in the foreseeable future and that they would have to follow the line. In other words, as far as historic cost and current cost accounts were concerned,

"We just have to be able to ride both horses."[FD]

Cost of Capital: Price Cap Regulation.

The other major regulatory issue raised in the context of the cost of capital debate was the question of the price cap. Having already noted the industry's general opposition to any 'drift' in the regulatory regime from price cap to rate of return regulation, reasons were sought for this position.

It is probably safe to assume that the monopoly suppliers of water would have been content to operate with little or no regulation. Given that the legislators took a different view, two broad approaches were considered workable in the English and Welsh water industry: a price cap or a cost plus rate of return system. The preference of the legislators was for the former, a view upheld by Ofwat in its various publications. This official line was spelt out in the 1991 Annual Report.

"There are advantages in maintaining price cap regulation, with incentives for the companies to reduce costs, rather than moving towards a cost plus system where revenues are directly set to cover costs, including a rate of return element. The nature of the water industry, however, means that there is a need to have particular regard to ensure a reasonable rate of return on capital when setting price limits at periodic reviews."[155]

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[155] OFWAT Annual Report 1991, p6.

This statement suggests that the choice in terms of regulatory regime is not a simple one, between pure price cap regulation and pure rate of return regulation. The picture is more complex than that. The choice is not 'either-or'. The fundamental difference is one of timespan.

In setting a price cap for a company operating in an industry as capital intensive as water some rate of return must be assumed. After all, a price cap is set with the expectation that over a period of time there is a reasonable prospect that an industry will be able to earn an appropriate rate of return. The question is, how often is the exercise undertaken? How often is the price cap reset? Consequently, how often is a target rate of return fed into the calculation? The more frequently this is undertaken, the more the regime is engaging in rate of return regulation. The more infrequent the reviews, the longer are operators allowed to conduct their business under the price cap. There is, in one sense, a continuum of regulatory positions between the two extremes. The position of any Regulator along this continuum may therefore be thought of as being determined by the frequency of price cap resetting exercises. From a shareholder's point of view the more infrequent the resetting of the price cap, the greater the risk/reward element; the greater the uncertainty.

The present regime (1989-92) was seen by one regulatory manager in exactly this way; embracing a series of five or ten year periods of price cap split up with rate of return exercises - the periodic reviews.

> "When you get to the periodic review you are talking about rate of return using the cost of capital and then you have another five or ten years of price caps. It's a fairly logical model" [FD]

Ian Byatt agreed with this view, regarding it as

"a stylised way of looking at it" [Byatt]

With one exception[156] the company officials were enthusiastic supporters of the price cap regulation. They appeared to resist any movement away from this regulatory position. Among the benefits cited were its simplicity, its promise of long run stability and security for company operations and consequently its positive effect in attracting private finance. Above all they recognised its part in enhancing management performance incentives,

"The price cap is the one thing that every company should have, which is an incentive to management to outperform. And it's really got to be that which is underlined. Not just utility companies but companies in monopoly positions do need something that's going to spur them. And there's no evidence in my view that the alternative based on what I've seen of regulation in the States, for example, is going to be any better." [FD]

Companies saw the price cap system as giving them freedom to operate as opposed to being subjected to,

"...intrusive annual reviews that you would expect to see under a rate of return regime [rather] than a price cap. Because under a price cap regime it should be accepted that if things turn our favourably for the companies then that's for the companies to hold. Because next year or the year after things might turn out completely the other way." [FD]

Although they were convinced that price cap remained the Director General's favoured regime many equated more 'active' regulation with an insidious drift away from its spirit. The promise of operating 'headroom' from a 'hands-off' Regulator appeared to be vanishing as the regime developed. Nevertheless, the companies' aversion to annual

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[156] A water only company's official with over 14 years experience of the industry.

reviews and rate of return exercises in general was given a new perspective by Ian Byatt. He pointed out that company risk-aversity, when faced with the prospect of rather longer periods of price cap operation had, in the initial settlement, led to the inclusion of,

> "...a lot of provisions for interim determinations. These provisions were put there by the companies. They wanted them because they wanted to reduce the risk. In so far as there is a rate of return aspect to it compared with just looking at it periodically on an annual return, they subsequently went there on the behest of the companies. There's a confusion sometimes between the notion of the annuality. I don't like annuality very much, I just happen to have been given a licence that's got a lot of annuality in it...Then the rate of return aspect seems to me in a capital intensive industry with a very big investment programme, it makes sense to talk about the rate of return and periodic reviews." [Byatt]

Given these comments it would appear that companies are generally seeking means to reduce risk whilst allowing scope for making greater rewards.

But the price cap model was not without its flaws. Chief among those cited was the need for long range budgeting. Even a five year time horizon was regarded by the companies as wholly unworkable. By the time the budget was published its assumptions had been overtaken by events. Politically the price cap was regarded as fragile tool in the hand of the politically appointed Regulator, with the potential to be turned rather too easily other uses. In this connection, one interviewee speculated that there might be some significance in the fact that the minimum time span for interim determinations (5 years) matched the maximum life of one Parliament; without wishing to enlarge on this. Finally the cost-pass-through 'safety-valve' built into the system and used in the case of South West Water[157], was regarded by the Regulator as being out of tune with the price cap regime. On this and other issues the forthcoming interim determination was anticipated by all parties as an opportunity for more clearly articulating the regime; redeeming the 'mistakes' of the past and setting a new course for the future. The success or otherwise of this process will ultimately depend on the informational resources available to Ofwat.

Overall, the question of rate of return as against price cap regulation appears to be a question of balance. Despite their reservations, companies and Regulator confirmed that the present solution of 5 or 10 year reviews appeared acceptable. Both parties were anxious to reduce the opportunities for regulatory intervention between reviews.

Regulatory Relationships.

The second general issue on which qualitative data was acquired was the question of regulatory relationships. Although much filtered information appears in the press from time to time on this question the data is, by definition, second hand. Personal interviews with the principal actors removes this filter. Many interviewees were quite candid about these questions, but some important data was obtained which illuminated the way in which relationships impacted on, or determined, economic events. This economic question is the relevant aspect of the work.

Ian Byatt was appointed Director General of Water Services on 1st August 1989. One month later his office (Ofwat)

[157] On 23/12/91 the Director General determined South West Water's K to be increased form 6.5 to 11.5 for each of the three years 1992/3, 1993/4 and 1994/5.

began preparatory work for the implementation of the 1989 Water Act.[158] As a civil servant, his task was to administer and operate a regulatory regime conceived by politicians and delivered in statute. Consequently, as was noted above, his influence over its initial form and substance was restricted.

A water-only-company interviewee summed up the initial position in the following way.

> "I think he [Byatt] saw when he came into office a certain amount of freedom within the price cap for the companies; which we believed, as far as the privatised companies were concerned, was a deliberate intention. Because privatising such organisations must leave a certain headroom for manoeuvre. And we, looking at that side of it from the outside felt the Government had done that deliberately. We also felt the Government wouldn't be averse to the regulator coming along afterwards, having got the money in for the privatisation, for the Regulator to try and clamp down. So I think he [Byatt] recognised a certain amount of looseness in the price cap, and couldn't do anything about it other than ask for a voluntary abatement of K because there wasn't an opportunity for clawback to be operated." [FD]

Comments should therefore be seen against the background of this work; a gradual tightening of the regulatory regime.

In some ways Byatt had a more difficult position than his peers in other industries. He was regulating an industry with rising prices, significant investment requirements, little competition and the right to seek cost pass through for certain expenditure. This undoubtedly shaped the way in which he interacted with industry officials.

During every interview the point was made that the regulation of the industry took place in highly charged political environment. This may have been a function of

[158] The duties of the Director General with respect to water and sewerage were set out in the Water Act 1989 s7.

interview timing, straddling the 1992 General Election. But clearly any regulatory regime implying interaction and relationship between the various parties also implies a political dynamic. According to one interviewee regulation was a 'political game'. And information and publicity were the primary weapons in the fight to balance the competing demands of national politicians, European politicians and consumers.[159]

In this task, Ian Byatt employed the tools of publicity. The role of publicity in creating an image for Ofwat was not lost on the Regulator. Press notices, radio and television appearances and glossy annual reports all raised the profile of the office. He viewed this as part of the job of communication, consultation and maintaining an 'open relationship'[160] with the industry. Annual visits to the companies, he said, went some way to building a 'personal rapport' which he saw as 'a prerequisite of effective regulation'[161] The openness to publicity and the public consultation exercises have marked the Regulator as one of the most open of his peers dealing with recently privatised utilities. A contrast may be made between these extensive and well publicised exchanges in the run up to price setting at the 1994 periodic review, and the rather less well publicised price setting exercises of organisations such as British Telecom.

Unsurprisingly, attitudes towards the 'personal rapport building' process varied from thinly disguised hostility to outright enthusiasm. As with all relationships Byatt's advances were received in different ways. He was regarded

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[159] One finance director labelled these the Westminster Effect, the Brussels Effect and the Esther Rantzen Effect.

[160] Ofwat Annual Report 1989 p9.

[161] Ofwat Annual Report 1990 p11.

by some as a benign dictator; the fatherly patrician who combined generosity of spirit with firm purpose. Others saw him less favourably as undertaking his tasks too enthusiastically, in the sense of engaging in company management too frequently by his various interventions. However, all were united in their respect for the capabilities of the man; his intellectual stature and his political astuteness. Company officials were in no doubt as to his potential as a powerful ally of the industry in pressuring other regulators and 'fighting the corner' for the industry against the various European bureaucrats.

These attitudes highlight a certain tension, recognised by Byatt, as he seeks to steer a course between two extremes. On the one hand a regulator could operate under rules which may be regarded as being completely 'objective' in some sense. The alternative is for him to follow a 'subjective' and completely idiosyncratic approach to regulatory policy making. The question remains unresolved, but the challenge is to strike a balance.

In terms of regulatory 'personal rapport' the fact that Ian Byatt is an economist by training is a matter of some concern to the company officials. The language of the Ofwat Annual Reports and Ian Byatt himself reflect this. Senior company finance executives invariably with an accounting background, regard sympathy with the world-view of an economist as essential to working in the regime. Indeed the view was expressed that Ofwat was 'dominated' by economists. Byatt himself was aware of the criticism and has had considerable experience of the efforts made to link the twin disciplines of economics and accounting in some logical structure.[162] Many companies remained unconvinced and still regarded the link as opaque. This, despite the

[162] See for example the Byatt Report (1986).

fact that Byatt had taken steps such as issuing accounting guidelines in a format identical to that adopted by those preparing Statements of Standard Accounting Practice.

Regulatory Relationships: Regulatory Risk.

One of the most obvious ways in which personal relationships have an economic impact is in the fact that the actions of the Regulator affect the stock market assessment of the industry's regulatory risk. This is important from the point of view of the cost of capital and hence the use of modified current cost accounts.

An important determinant of the cost of capital is the degree of risk, regarded as being very low in the regulated water industry. One finance director characterised the industry as 'gilt edged' protected as a natural monopoly by the prohibitive cost of duplicating fixed assets. Nevertheless a level of risk exists and is perceived as being significantly affected by Ian Byatt's behaviour and use of publicity . The 'Cost of Capital Consultation Paper' was regarded with open hostility as one way in which risk had been raised, although one finance director expressed the opinion that the Regulator did not want to drive the companies out of business through an unreasonably low cost of capital.

Evidence on share price movements was offered to suggest that stock market valuations were very sensitive to regulatory initiatives. And that this, rather than any fundamental change in the earnings growth potential of companies, determined short term price fluctuations. Once more, companies were critical of any regulatory initiatives which had a detrimental effect on their market valuation. They regarded regulatory inactivity as desirable for the reason that regulatory risk assessment would be held down.

Regulatory Relationships: Regulatory Capture.

Although the building and maintenance of personal relationships between regulator and regulatees is an important aspect of the work, the danger is that this relationship becomes too close and that the regulator is effectively 'captured'. The firm impression from the interviews was that this had not taken place. And whilst the initial settlement had been heavily influenced in the industry's favour and given its hallmark, since then there was no suggestion that the exercise had been repeated. The view of the Regulator as a benign dictator adds weight to this argument. As one finance director noted,

"So there's got to be a good working relationship. But for that to become too cosy reduces the problem of the Regulator to being one of part of the industry instead of the champion of the consumer. However the most noticeable aspect of his stance to me anyway, is his publicity, which he's quite keen on and he uses every opportunity. I'm not sure whether it's entirely for the benefit of the consumer or for Ofwat."[FD]

Underpinning this regulatory independence was Ofwat's possession and use of information. In any principal-agent setting the possession of information is central to the interaction of the parties. Indeed the essential regulatory problem is a problem of asymmetric information. Therefore information, confers bargaining strength on its possessor. The point was not lost on Ian Byatt,

"I think that especially when I was trying to regulate 30 odd companies, having a lot of good information is critical. It's critical to the ability of the Regulator, it's also critical to the credibility of the regime of the information, so that people can understand what's going on. So much of the information which is around is not of a very comprehensible form."[Byatt]

Undoubtedly the ministrations of Ofwat have increased the quantity of data coming out of the industry. But more significantly they have improved its quality and consistency. Where companies formerly reported various output measures, often peculiar to themselves, now 'water delivered' has been established as the cornerstone for company performance measurement. Many companies said that they used these innovations as a spur to improve their own information systems. But there was little doubt that improved information flows in favour of Ofwat had gone some way to tipping the balance of power away from the companies who were at their zenith during privatisation.

Increased information requirements were frequently cited as an example of the 'intrusive' nature of the regulation. Although it was, and remains, the stated aim of Ian Byatt to remain at 'arms-length' from the day to day operations of the industry[163] many companies saw the informational demands as an unwarranted 'interference' in the affairs of the company. A slightly different perspective on the problem was given by one finance director. He saw improved output information eventually unravelling the knot of regulatory intervention. His argument was that if the output measures were 'got right', regulatory interference would diminish. Byatt, he maintained, only required so much input and other information because output measures were currently so poor. The 1989 Ofwat Annual Report appeared to confirm this:

> "I shall regulate by reference to outputs - what the customer receives and what he or she pays for - rather than by inputs, because the industry should be allowed to allocate its resources in the most effective way."[164]

Nevertheless, the idea has yet to be accepted by other officials such as the following who stated,

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[163] OFWAT Annual Report 1990 p12.

[164] OFWAT Annual Report 1989 p 10.

"What has happened is that there's been a great development in information systems and consequently the data that you would be using in the old authorities has been improved upon. Ofwat has actually played a part in that because of their intrusive sort of regime. They require fantastic amounts of information." [FD]

Ofwat's wide and deep trawl for information also reflects the breadth of its remit. Trying to pin down one over-riding regulatory priority on this or any other basis proved very difficult. Priorities cited included customer service, price control, the promotion of efficiency, the promotion of metering and the general interest of shareholders. But many of these offerings were qualified by the observation that there was a 'regulatory balance' to be maintained. Whilst this was confirmed by the Regulator, his view as at May 1992 was,

"I suppose when the chips are down it's the level of prices that's going to matter most." [Byatt]

Which is a wholly appropriate view for an economic regulator operating a price cap regime.

One other issue included only as a supplementary question received much interesting comment. In the wake of several well-publicised mergers and the introduction of the more rigorous system of comparisons, opinions were canvassed on the optimum size of a water-only-company operating under the current regime. Several views emerged. Among them were; that managerial considerations greatly influenced a company's optimum size: two regulatory managers asserted that large units similar in size to the water and sewerage companies were of optimum size whilst another confessed to having no idea. The response of Ian Byatt was predictably non-committal.

"I don't think that it's part of the Regulator's job to have a view about the structure of the industry and therefore to go into a lot of static economic comparisons of these things. I think it's much more important to maintain enough comparators to see changes in the structure of the industry, in the number of companies only when there are very good reasons for doing it." [Byatt]

Nevertheless, with these exceptions a remarkable unanimity emerged. The point was made that water was a parochial commodity, a heterogeneous local resource which required a supplier very well appraised of local conditions. The view of both water only and water and sewerage officials was that the bigger companies were probably too big, too distant from the customer and remote. Their size meant lines of communication from consumer to producer were necessarily longer and information messages travelling along them were attenuated. Whilst the general integrated river basin management principle was seen as valuable there was a case for breaking up the very large local monopolies. At the other extreme the smallest statutory companies were probably too small. Their position had been tenable only through their access to good resources. But under the new regulatory regime, demands for large quantities of information were difficult to meet. Although more in touch with the customer, companies were simply not large enough to carry the substantial overheads. The general view of optimum size appeared to be that of the larger statutory companies. Small enough to remain near to the customer, large enough to carry the regulatory burden.

Conclusion.

In concluding the chapter it is necessary to draw together some of these rather disparate lines of argument and opinions reported above.

In a sense we have come full circle. We began by arguing that, following Holmstrom and Shavell's result any addition to information is valuable in improving economic outcomes. The Shleifer approach to yardstick competition led us to argue that even marginal improvements in comparative efficiency measurement could have benefits in terms of regulatory outcomes. The acquisition, possession and use of information proved to be recurrent themes in all the discussions. Underlying the important questions of the cost of capital, the current cost accounting and price cap debates, was the issue of reported figures giving reliable data on economic stocks and flows. Underlying the questions of regulatory relationships, regulatory risk and regulatory capture, was the issue of the acquisition and control of information. Throughout, the use of comparative information appeared to be a strong driving force to increased levels of activity.

Controlling for heterogeneity, and the arguments for and against historic cost accounts surfaced frequently as issues of concern to finance directors. The Regulator appeared clear in his own mind that the second question had been resolved, but that the first required closer attention.

Industry officials also revealed that, although much early comparative work concentrated on operating cost in the context of the water supply function, neglecting the more difficult questions of sewage treatment and capital costs; its value was clear. New personnel drawn into the industry following privatisation, in particular, have used comparisons as a means to drive efficiency improvements. Clearly acceptance of the results of the work must preceed any effect it has on company operations and much scepticism still surrounds the more elaborate attempts at comparative efficiency measurement. Yet even informal comparisons have apparently driven efficiency savings and forced the hand of management in several ways. Yet companies continued to be aware that yardstick competition was not understood by the public and that much work remained to be done in convincing them of its efficacy.

The above qualitative data appears to have clarified certain issues pertinent to the analysis of yardstick competition, but not susceptible to quantitative analysis. Firstly over the use and understanding of the terms 'yardstick' and 'comparative' competition. The Regulator appears to take a more relaxed stance in respect of its implementation than that feared by the companies. Secondly, that by introducing the regime, even in this imperfect form, collusion between companies has been inhibited. Rather than seeing the implementation of yardstick competition as an unattainable long run goal, the general view of Regulator and industry is that incremental improvements are being, and will continue to be made. In terms of the attitude of companies to the system, the Regulator has achieved much in a relatively short time. Although much opposition remains - for example on the particular question of the place of modified current cost accounting. From an original position of muted enthusiasm there is now more general acceptance of these devices.

Comparative efficiency measurement for yardstick competition was heralded as a powerful instrument in the new regulatory regime established in 1989. As time went on the great expectations were not completely fulfilled. Questions still remain about its feasibility, nevertheless the principle is well established and accepted by the industry. Practically its operation is improving by stages. The 1994 interim review of the price cap promises to take the regime forward a long way in the drive to implement a system of yardstick competition. As one finance director stated,

> "There is an acceptance on the part of the industry for there to be some kind of yardstick competition. There is a definite view within Ofwat that there must be such a thing and therefore it will come about." [FD]

Appendix.

Extract from:
RAG 1.01 Guideline on Accounting for Current Costs, Ofwat, 1991, Birmingham. (p16)

Real FCM Retained Profit = Increase in reserves
- RPI x Opening Shareholders funds

where

'Increase in Reserves' = HC Retained Profit
+ Nominal gains on assets not recognised in HC profit
- Nominal gains recognised in HC profit in this period and not previously so recognised

and

'RPI x Opening Shareholders' Funds' = RPI x Opening fixed assets
+ RPI x Opening working capital
- RPI x Opening net finance

Fixed Asset Adjustments

With the above assumption and simplifications, the fixed asset adjustments can be derived as follows:

'Nominal gains on fixed assets not recognised in HC profit
- Nominal gains recognised in HC profit in the period not previously so recognised
- RPI x Opening fixed assets'

= (Closing CC fixed assets - Opening CC fixed assets)
- (Closing HC fixed assets - Opening HC fixed assets)
- RPI x Opening CC fixed assets

= (Opening CC NBV + RPI x Opening CC NBV + AMP/SIR Adjustment + Additions - CC NBV of Disposals - CC Depreciation - Opening CC NBV)
- (Opening HC NBV + Additions - HC NBV of Disposals - HC depreciation - Opening HC NBV)
- RPI x Opening CC NBV

= AMP/SIR Adjustment
- (CC Depreciation - HC Depreciation)
- (CC NBV of Disposals - HC NBV of Disposals)

Note:
AMP / SIR Adjustment is the revision in the real value of assets arising periodically from improved information, notably in AMPs and SIRs.
AMP = Asset Management Plan
SIR = Surface Investment Requirement

Chapter 8.

Conclusions.

The thesis set out to answer the question as to whether or not yardstick competition could work. In other words, how effective was the regulatory system described by Shleifer when applied to a particular industry? In this, the water and sewerage industry in England and Wales was chosen as an appropriate testbed.

In tackling the question, two related pieces of research were undertaken. First was the econometric estimation of a series of cost functions for the water and sewerage branches of the English and Welsh water industry. The purpose of this was to assess the tractability of an econometric method of comparative efficiency measurement. It was shown that a workable system of this sort was a prerequisite for the implementation of yardstick competition. Secondly, fieldwork was undertaken. Interviews with the industry's Regulator, and finance directors of a sample of the companies, enabled the development of a richer picture of the workings of the regulatory system in the industry.

Several general conclusions were arrived at. Given the necessity of comparative efficiency indicators for the operation of a system of yardstick competition it was important to confirm at least one way in which they could be derived. The econometric methods proposed for this work have not been adopted by the Regulator or companies to date, and are therefore pioneering. Furthermore, using these methods it was shown how a robust set of comparative efficiency rankings could be derived for both the water and sewerage sides of the industry. The rankings were robust with respect to the estimation method employed; this in spite of the rather poor data used for the study.

Evidence was also presented to confirm that the principle of yardstick competition had been part of the 1989 regulatory settlement and that it had since influenced the Regulator's industrial policy. And although yardstick competition was not fully operable from the beginning, since then, policy reforms had produced incremental improvements in the operation of the system and these continued to take place.

Qualitative evidence led to the rejection of Stelzer's (1988) argument that yardstick competition was too weak and remote a goad to performance. On the contrary, the finding was that both competitiveness and efficiency had been enhanced since the introduction of the new regulatory regime. And that part of the reason for this was the yardstick comparisons being made for the first time. However there was little quantitative evidence available as yet to either confirm or refute the view. In general, it was argued that regression techniques had a place in comparative efficiency measurement within the industry.

More specific conclusions were derived from the component pieces of work. Chapter 4 demonstrated ways in which comparative efficiency measurement for the water supply function could be undertaken, which gave robust ordinal rankings. It was found that economies of scale over the period examined were largely exhausted, but pointed to the fact that the service of more densely populated areas tended to lower the unit costs of service. Apart from one outlier in the sample, the Regional Water Authorities appeared to offer a relatively more efficient service than their statutory counterparts. This, despite the fact that the water only statutory companies generally served very densely populated areas and that this fact would have suggested a lower unit cost of service.

In addition, results confirmed the work of Spady and Friedlaender (1978) that hedonic specifications led to a greater degree of consistency in rankings across definitions of cost, and were therefore to be preferred. In the same vein, price factors displayed relatively little cross sectional variation over the sample and therefore appeared not to be the crucial element in determining the cost function. The effects of price were swamped by the effects of physical conditions in the measurement of comparative efficiency.

Similarly, for the sewerage treatment and disposal functions analysed in Chapter 5 it was found that robust comparative efficiency rankings could be derived. With cross sectional, rather than panel data the existence of substantial economies of scale in sewage treatment and disposal was confirmed. Once again the characteristics of sewage flow and sewerage arrangements had a significant impact on costs and tended to swamp the price variables in the comparative efficiency assessment. This led to the conclusion that work on so called 'explanatory factors' was vital for the modelling; particularly where the greater heterogeneity of sewage meant that the various processes were more difficult to model than those of water.

The results were consistent with the assertion that regulation may be more vigorous for works that discharge visibly more unsightly effluent than those discharging equally polluting but less visible effluent with high BOD levels. However, given the wide variation in estimates of efficiency another, tentative, conclusion was that the operators themselves had no clear way of judging the efficiency of their operations. As is still the case, considerable ignorance appears to surround assessments of comparative efficiency in this branch of the industry in particular.

As already mentioned, the data underlying the conclusions of Chapter 7 were qualitative rather than quantitative in nature. The conclusions were no less valid because of this. As has been mentioned above, one of the main conclusions was that comparative efficiency measurement has led to enhanced efficiency and competitiveness in the industry since 1989. The view of industry officials and the Regulator was that the final regulatory settlement did embrace the notion of yardstick competition, but that this was not fully operable at the time. The privatisation settlement, conceived and implemented by the Government was apparently very favourable to the water companies for reasons outlined above. Ian Byatt had inherited settings of price and conditions which were rather generous to the companies and their shareholders. One view that could be maintained was that the initial price cap settings were not founded on any rigorous objective assessment of comparative unit costs. The technical tools for undertaking the task were not available at the time. Rather the settlement came about following a protracted, political process of negotiation. However, the view was that, since then, the Regulator had set about redeeming the position by tightening up the regulatory regime in stages.

Significantly, it appeared that the informational cartel of the statutory companies had been broken by the reform of the regulatory regime, and that collusion between companies was effectively inhibited. Consequently, companies saw themselves as competitors rather than industry partners. Hence the conclusion that yardstick competition had improved performance incentives for company management.

In terms of the future, it was clear that both the

Regulator and his industry were committed to the concept of yardstick competition (Byatt preferred the term 'comparative competition'). The general view was that, whilst the system suffered from severe imperfections at present, it would improve incrementally as the quality of data and sophistication of analytical techniques were developed.

From the interviews it appeared that the issue of controlling for company heterogeneity in comparisons (the level playing field) was one of the most important to the Regulator and industry officials. The results of Chapters 4 and 5, the specification of hedonic cost functions address those concerns directly. And may, arguably be a useful tool for the Regulator in his work.

Limitations.

But almost as important as the statement of conclusions reached is a note about the limitations of the work. The research was ringfenced in certain important respects. Therefore it is essential to consider what questions the thesis did not set out to answer and what opportunities still exist for the research to be extended.

Although the empirical analysis of Chapter 4 employed data drawn from publicly and privately owned companies operating side by side the question of the relative efficiency of public and private companies was addressed only in passing. This, and other property rights issues were strictly outwith the remit. However it may be noted that the water industry over the period 1974-89 would offer a very useful testbed for many of the property rights questions. During that period, unusually for the UK, public and private companies operated side by side in different geographical regions to provide a similar service. Future research could usefully employ data from this period to focus on the comparative efficiency measurement question explained in terms of property rights theories. One of the chief obstacles to this sort of work would be the disentangling of pure 'ownership' effects from the effects on company performance of location and customer profile.

Another limitation was that empirical work used data covering the pre-privatisation time period. Reasons for this included the lack of a sufficient quantity of data post-privatisation, and the advantages of conducting the analysis at a time of comparative institutional stability. Whilst this was sufficient for the purpose in hand, ie demonstration of the feasibility of comparative efficiency measurement by econometric methods, there was a trade off. It was not possible to arrive at conclusions concerning company efficiency and whether or not it had improved since the reform of the regulatory regime. As time goes on, and consequently as more data points become available, an extension of the work in this direction will become possible. Indeed, the prospects for improved results are bright given Ofwat's commitment to the development of reported data of enhanced quality and quantity.

Underpinning all the empirical work were the results of Shavell (1979) and Holmstrom (1979) discussed in Chapter 2; that any addition to an information set, no matter how imperfect, would improve contracting in a principal-agent setting. Given the limitations of data this proved vital in the study. Shleifer's (1985) observation, that only a ranking of firms was required to give the right incentives in a system of yardstick competition, made the approach taken feasible. The object throughout was not to derive absolute measures of firm efficiency, rather find efficiency rankings for firms that were robust with respect to the estimation method employed. Therefore, any more detailed measures, although interesting, would be surplus to requirements. There remains scope for further work in this area, to derive absolute efficiency measures and therefore to assess the potential each firm has for making efficiency improvements. Given the difficulties of controlling for company heterogeneity and the fact that companies operate in a dynamic rather than static economic environment, the task is non-trivial.

This comment leads on to one final caveat concerning the work. Although the results may be used productively in the various ways outlined above, they are founded on static economic analysis. The question of regulatory dynamics has not been addressed. In terms of technical competence this would require a whole new approach to be taken. The problem is noted but not resolved in the work presented here. With economic analysis of the industry at such an early stage of development much static work remains to be completed.

Policy Implications.

Finally, what policy implications may be drawn from the work? Are there any general principles which may be established which would guide a policy maker towards or away from employing a similar regulatory solution in other industries? Is yardstick competition a more widely applicable regulatory device?

The basic conditions laid down by Shleifer for the working of the system appear to be a reasonable guide to this question. Paramount is the requirement of a series of local monopolies supplying similar commodities in differing areas. Accounting for heterogeneity in terms of service regions proved to be very difficult indeed in the case of water. The question of establishing a 'level playing field' on which to make comparisons is one of the earliest and most difficult that any regulator must tackle. Therefore in applying the solution to other industries, much preparatory work must be conducted in this area, and broad agreement reached on the explanatory factors to be taken into account when making comparisons. Either operators must serve identical regions, or agreement must be reached over accounting for heterogeneity.

An industry such as telecommunications would have appeared an attractive candidate for yardstick competition treatment a decade ago. Although one supplier dominated the market it may be argued that in terms of domestic calls the market could have been split up into a series of local monopolies.[165] With this industry structure giving a large number of comparators, yardstick competition may have been appropriate. However, given the recent pace of technical change, opportunities now exist for increased competition even in local areas. Technological advances have lowered market entry barriers to the point where the characterisation of the service as a natural monopoly is questionable. For yardstick competition to work effectively it must be the case that local monopoly situations are likely to persist; a slow rate of technical change is required. Water and sewerage services meet this requirement, telecommunications services do not.

Given that local monopoly conditions must persist, the chief candidates for implementation of this type of regulatory regime are the public utilities, gas and electricity. And whilst extraction and generation operations may be opened up to competition the distribution function is apparently naturally monopolistic. Distribution is, however, a capital intensive activity, as was the case

[165] The City of Kingston upon Hull operated successfully during the period as a local telecommunications monopolist in Hull and the surrounding area.

for water. Regional distributers may therefore be candidates for yardstick competition but the question of capital valuation must be resolved. The cost of capital was seen to be one of the most intractable questions facing the water industry. Therefore as a prerequisite agreement must be reached on conventions to be adopted over the measurement of capital stock and its cost. Reliable information systems are necessary if the solution is to be implemented.

One other drawback of the system mentioned by Shleifer, strategic manipulation, should also be acknowledged. Close cooperation between operators must, to some extent, be supplanted by competitive behaviour. And whilst, in theory, only two companies are required for the operation of yardstick competition it may be the case that with a duopoly strategic manipulation of information and tacit collusion are almost inevitable. Consequently, following the comments of Ian Byatt, there may be a bias towards maintaining a higher number of comparators.

In the English and Welsh water industry it would appear that the prospects for yardstick competition covering the water supply function are more positive than those for sewerage. With only ten sewerage comparators available, controlling for company heterogeneity would appear to be more problematic. A reduced number of comparators implies reduced information on heterogeneous circumstances under which companies operate. Given the difficulties encountered with a system using over thirty comparators, it may be argued that with less than half that number of comparators, the problems of implementation are multiplied many times. The feasibility of such a system should be called into question.

There is, however, one other area in which the yardstick regulatory solution may have a role: the Scottish water and sewerage industry.

As part of the ongoing consultation process over local government reform, the Scottish Office issued a consultation document on the future of the water and sewerage industry in Scotland[166] in November 1992. At present these services are the responsibility of the nine Regional, and three Islands, Councils. The document highlighted the Government's intention to reform the industry's structure and regulatory arrangements. Given the English and Welsh experience discussed above, there appears to be some scope for using comparisons among service providers to substitute for market disciplines in securing an efficient allocation of resources. The Scottish industry has many operational, legal and technological similarities with its southern neighbour. It is an industry comprised of local natural monopolies, charged with delivering a service to standards laid down in British and European statutes. Given these characteristics, the Shleifer regulatory solution (or some variant) would appear to be appropriate.

Regardless of whether ownership remains in the public sector or is transferred to the private sector, it may be argued that there would be regulatory benefits to be gained from bringing the Scottish industry within Ofwat's regulatory remit. These would include access to intellectual, administrative and technical expertise built up since 1989. And most significantly, from the point of view of yardstick competition, Scottish comparators would be added to the pool. Clearly there would be many other issues to be considered. The differing political and institutional dynamics would determine which ownership option would be chosen. This may add considerable, perhaps

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[166] 'Water and Sewerage in Scotland: Investing for our Future.' (1992) Scottish Office, Edinburgh.

insurmountable, difficulties to the implementation of such a system. However, a working model of cross border regulation already exists for one industry with some of the characteristics of a natural monopoly; electricity.

The Office of Electricity Regulation (Offer) has responsibility for operators north of the border and operates from an office in Glasgow under a Deputy Director General. The office oversees an industry structured in a radically different way from its southern counterpart. And although addressing a slightly different set of issues, the Scottish operation is in a position to draw on the wider resources and experience of Offer.

It may be argued that the arrangement may be extended to water; and in terms of yielding more comparators, would benefit the whole industry, north and south. This would, of course, commit the Scottish regulator to a particular style of operation. Nevertheless, as with electricity, it may be possible for a Scottish operation to draw on Ofwat's regulatory expertise whilst administering a system tailored to a radically different industrial structure. The further information on activities in regions with abundant resources would enable the Director General to make more informed decisions over the setting of price levels, particularly in the north of England and Wales where conditions are similar to those in parts of Scotland. Overall, it would appear that, whilst a direct translation of regulatory policy may be inappropriate, some examination of the experience of Ofwat and its attempts to implement yardstick competition, should inform the Scottish debate.

Future.

There is, in the water industry, a guarded optimism about the future development of a system of regulation embracing the principles of yardstick competition. As predicted by its originator, Shleifer, the system in all its purity has been shown to generalise to cover an industry in which heterogeneous local monopolies serve heterogeneous areas.

Even at this early stage of development it has begun to reveal the cost minimising potential of yardstick competitors in one sector, and to establish an incentive structure more appropriate to the achievement of that potential. Much remains to be done, but much has been achieved since Stephen Littlechild first suggested that this may be the solution to the regulation of the English and Welsh water industry.

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